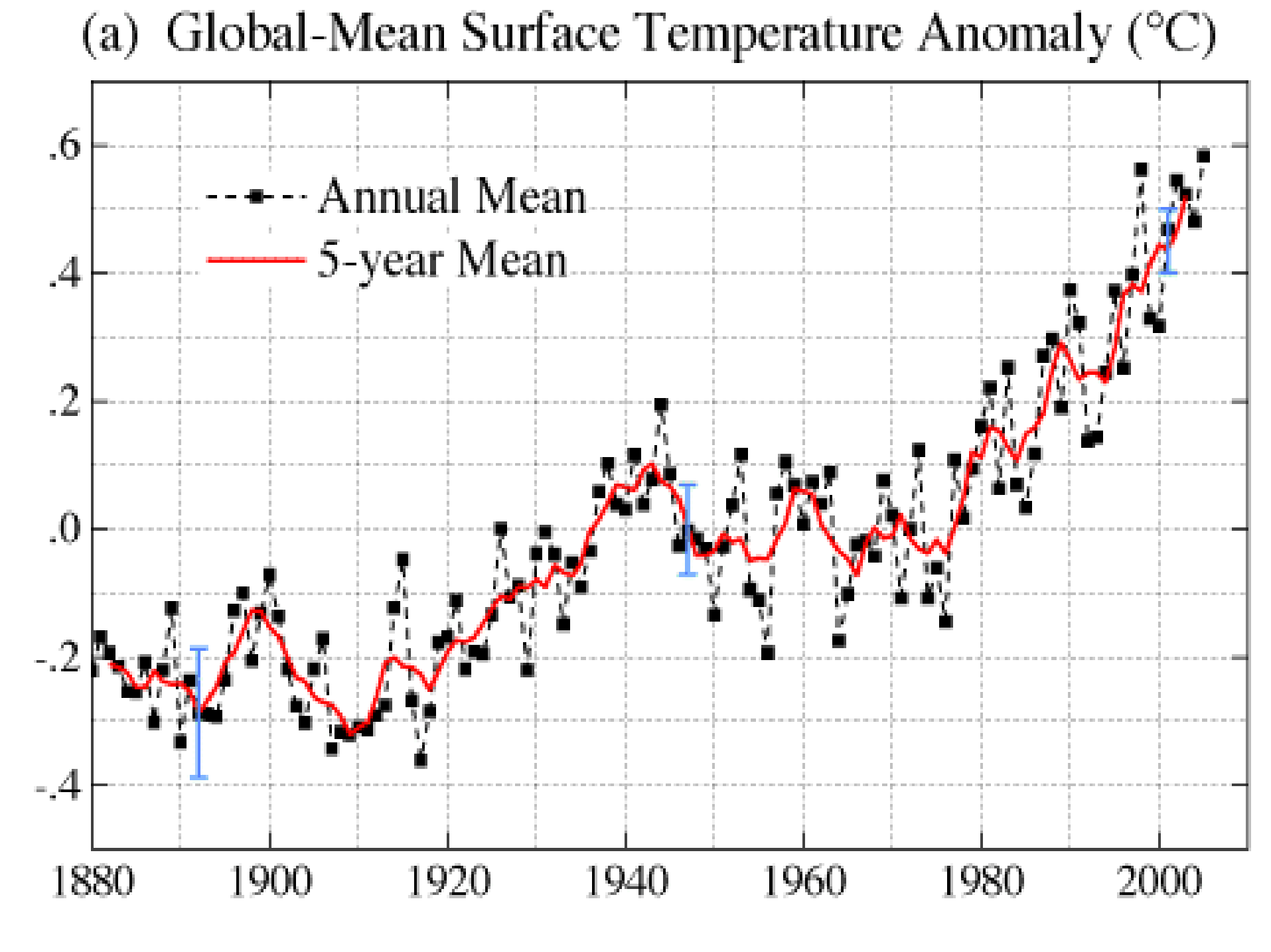
International Science Forum on Computational Toxicology

John S. Petterson, Ph.D.
Sequoia Foundation &
Impact Assessment, Inc.

It's not the Warming. . .
it's the When and Where of Water

May 21–23, 2007
U.S. EPA Main Facility
Research Triangle Park, NC


(a) Global-Mean Surface Temperature Anomaly (°C)
Annual Mean
5-year Mean
.6
.4
.2
.0
-.2
-.4
1880
1900
1920
1940
1960
1980
2000

1980-2006 Global Temperature Anomalies

NASA/Goddard Space Flight Center Scientific Visualization Studio

Overview

- **Global Climate Change**
  - Rapid warming at Poles
  - Modest warming at mid-latitudes
  - Less warming at equator
- **Changes in Precipitation Patterns**
  - Wind patterns (evapotranspiration)
  - Geographic distribution of rainfall
  - Volume of rainfall
  - Timing and periods of rainfall

Overview

- **Effects on Human Health**
  - **Direct morbidity/mortality effects**
  - **Indirect morbidity/mortality effects**

Three Perspectives

- **Lake Chad Basin (Niger, Chad, Nigeria, Cameroon) (GCC vs. locally-induced impacts)**
- **Hurricane Katrina (peak climate event and human folly – ignoring the obvious)**
- **China (climate- vs. regionally-induced impacts)**

Final Report

UNDP/ World Bank/ GEF Project
Reversal of Land and Water Degradation Trends in the Lake Chad Basin Ecosystem

Environmental and Social Risk Assessment (ESRA)

(Evaluation des Risques Environnementaux et Sociaux (ERES) Dans Le Bassin du Lac Tchad)

Submitted to:

Lake Chad Basin Commission
Commission Du Bassin Du Lac Tchad

Submitted by:

Impact Assessment, Inc.
2166 Avenida de la Playa, Suite F
La Jolla, California 92037

July 17, 2006

Final Technical Report

Preliminary Assessment of the Impacts of Hurricane Katrina on Gulf of Mexico Coastal Fishing Communities

Submitted to:

U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southeast Regional Office (SERO)
263 13th Avenue South
St. Petersburg, FL 33701

Submitted by:

Impact Assessment, Inc.
2166 Avenida de la Playa, Suite F
La Jolla, California 92037

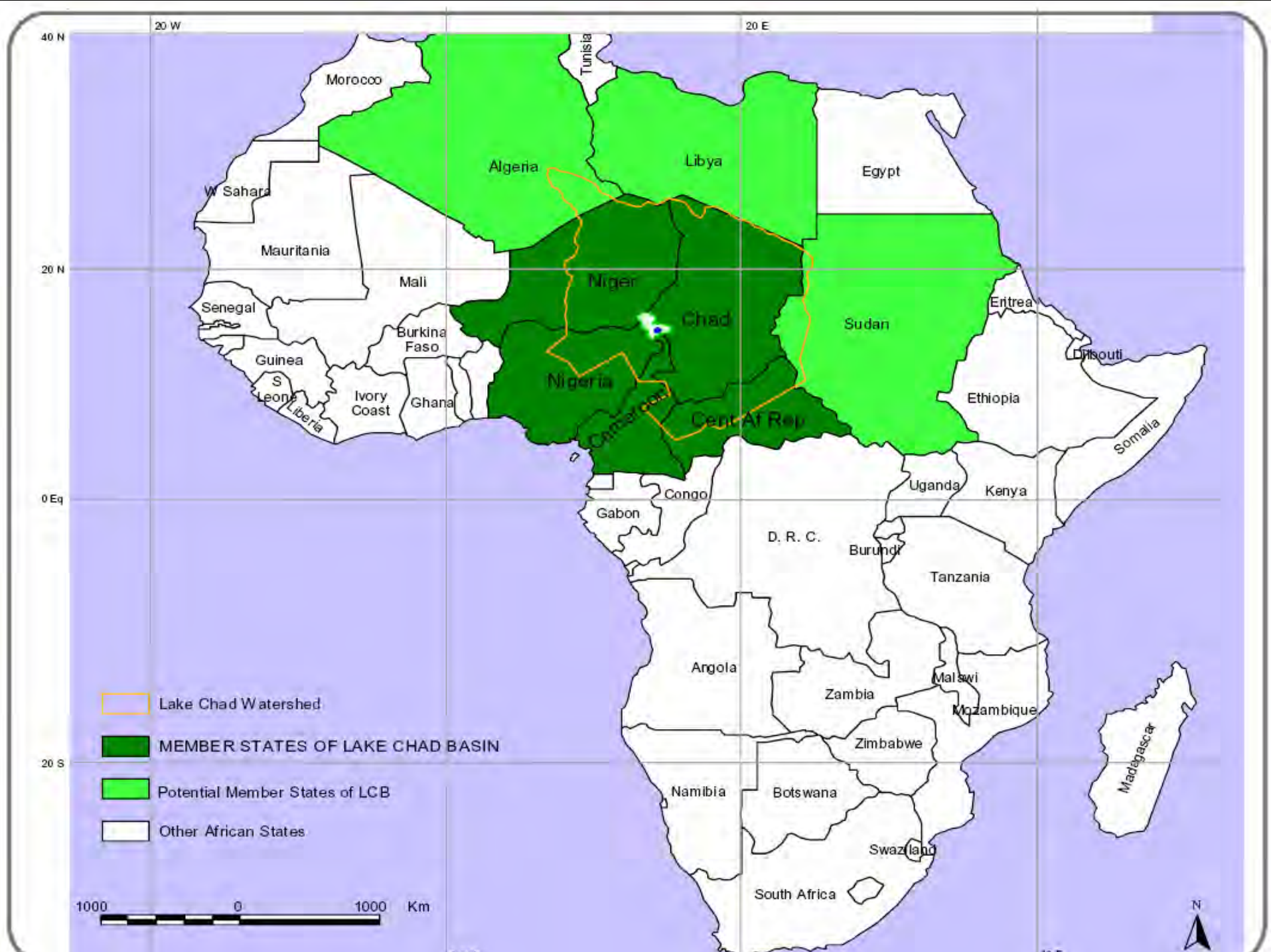
August 2006

Lake Chad Basin (UNDP)

- **Background:**
  - **Among all the major hydrologic basins of the world, Lake Chad considered by the FAO to be the most adversely affected by global climate change**
  - **Declined from about 25,000 square kilometers in size (1963) to today's 1,350 square kilometers**

Lake Chad Basin (UNDP)

- **Study objectives:**
  - **Identify environmental risks posed by GCC and the nature of those risks, to long-term water supply (agricultural, pastoral, and fisheries resources) at the level of the basin and its sub-basins;**
  - **Identify the local level human-induced contribution to environmental degradation; and,**
  - **Provide recommendations and guidance on long-term resource management policies and priorities at the basin level.**


20 W
20 E
40 N
20 N
0 Eq
20 S
Morocco
Tunisia
Algeria
Libya
Egypt
W Sahara
Mauritania
Mali
Niger
Chad
Sudan
Eritrea
Djibouti
Senegal
Burkina Faso
Guinea
S Leone
Liberia
Ivory Coast
Ghana
Nigeria
Cameroon
Cent Af Rep
Ethiopia
Somalia
Uganda
Kenya
Congo
Gabon
D. R. C.
Burundi
Tanzania
Angola
Malawi
Zambia
Mozambique
Zimbabwe
Madagascar
Namibia
Botswana
Swaziland
South Africa
Lake Chad Watershed
MEMBER STATES OF LAKE CHAD BASIN
Potential Member States of LCB
Other African States
1000
0
1000
Km
N


10°E
15°E
20°E
25°N
20°N
15°N
10°N
5°N
Libya
Algeria
Niger
Chad
Sudan
Lake Chad Hydologic Basin
Lake Chad
Lake Chad Conventional Basin
Nigeria
Cameroon
Central African Republic
Zaire

A Chronology of Change

Natural and Anthropogenic Factors Affecting Lake Chad

Water

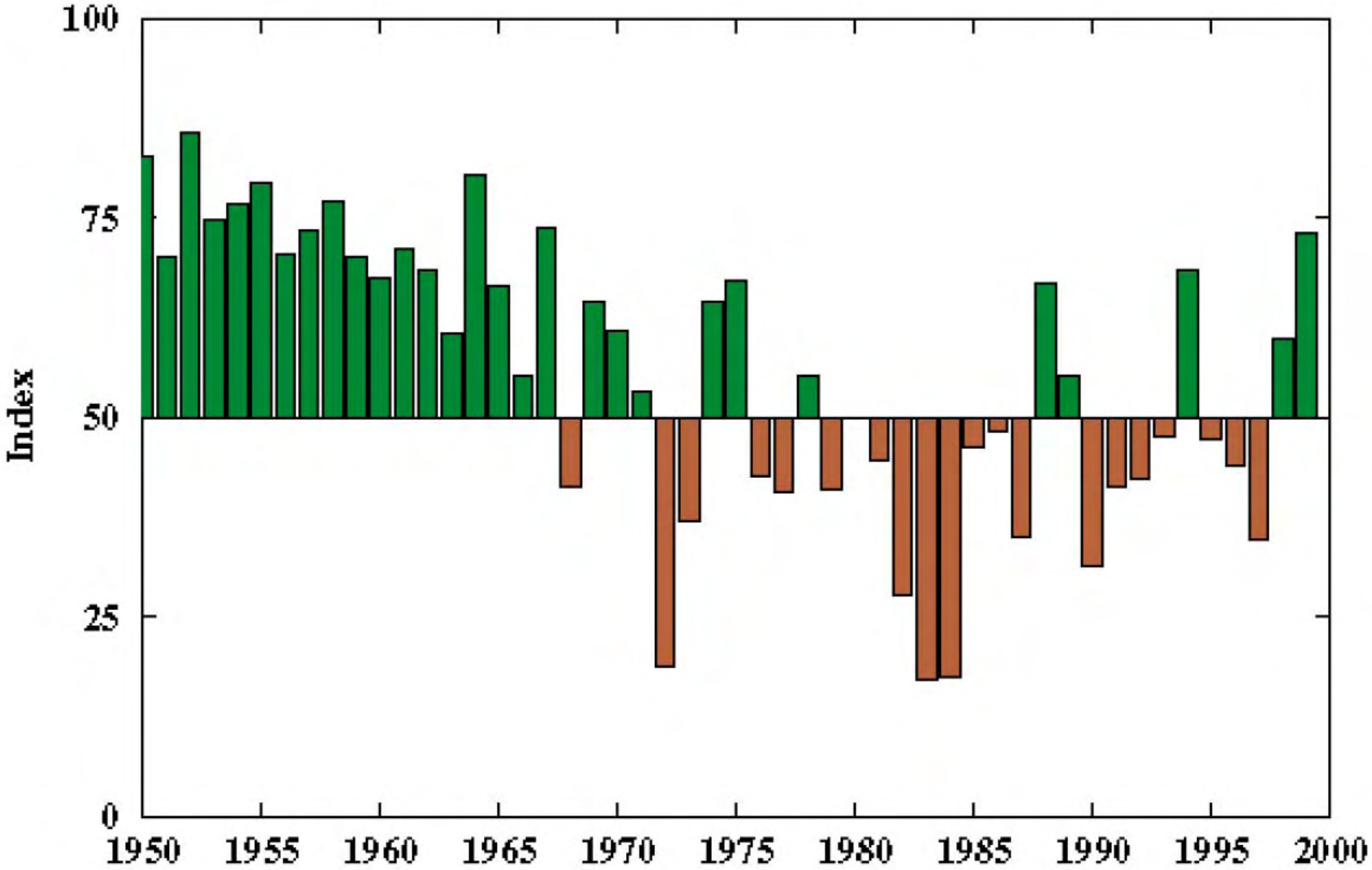
Former shoreline

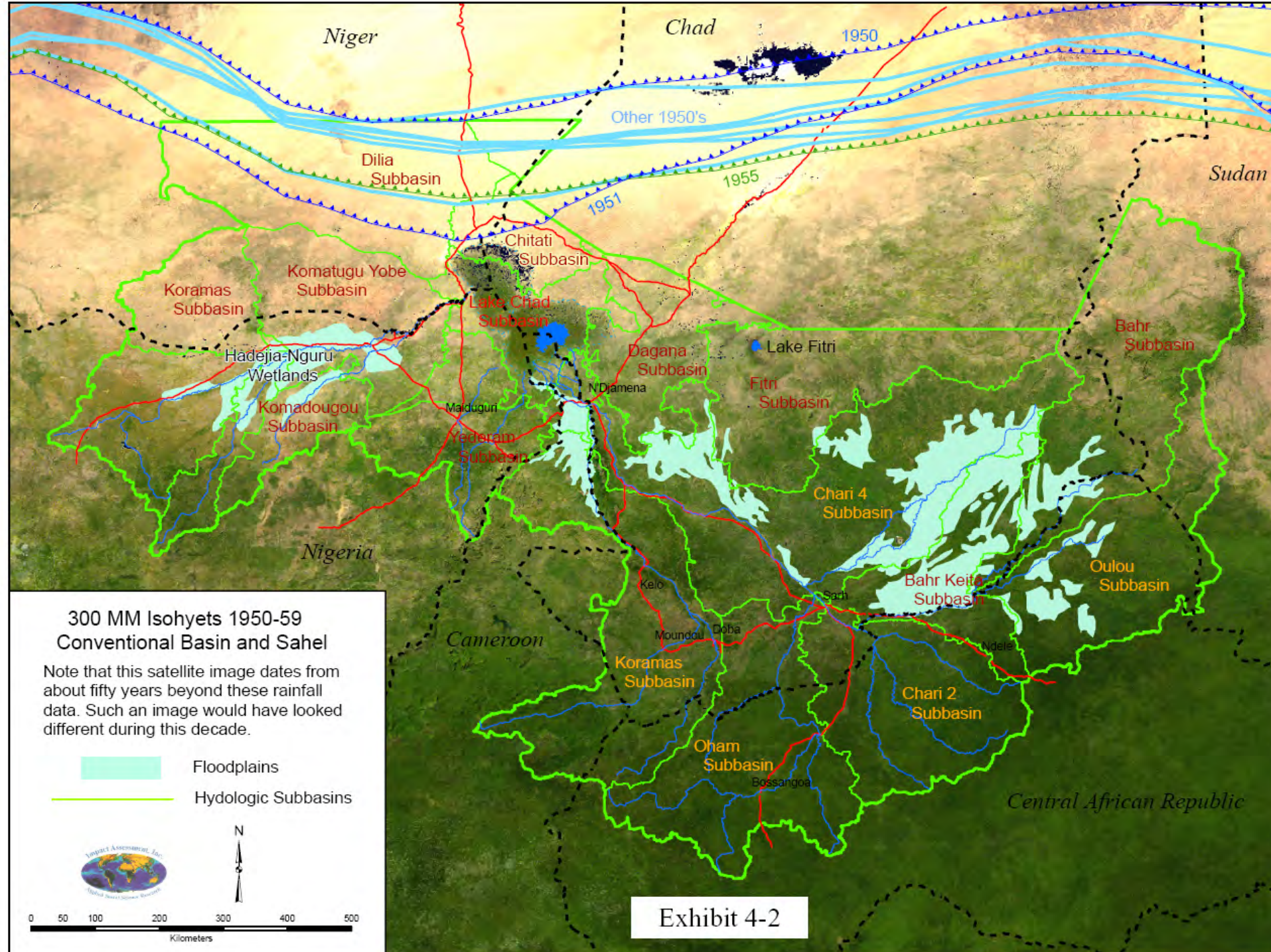
Vegetation

This collection of maps has been sourced from a series of satellite images provided by NASA Goddard Space Flight Center:

http://www.gsfc.nasa.gov/gsfc/earth/environ/lakechad/chad.htm

Sahel Rainfall Regime: 1950-2000




Niger
Chad
Sudan
Nigeria
Cameroon
Central African Republic
1950
Other 1950's
1955
1951
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Komadougou Subbasin
Yedseram Subbasin
Maiduguri
N'Djamena
Dagana Subbasin
Lake Fitri
Fitri Subbasin
Bahr Subbasin
Chari 4 Subbasin
Bahr Keita Subbasin
Oulou Subbasin
Sarh
Kelo
Moundou
Doba
Ndele
Koramas Subbasin
Chari 2 Subbasin
Oham Subbasin
Bossangoa
300 MM Isohyets 1950-59
Conventional Basin and Sahel
Note that this satellite image dates from about fifty years beyond these rainfall data. Such an image would have looked different during this decade.
Floodplains
Hydrologic Subbasins
N
0 50 100 200 300 400 500
Kilometers
Exhibit 4-2

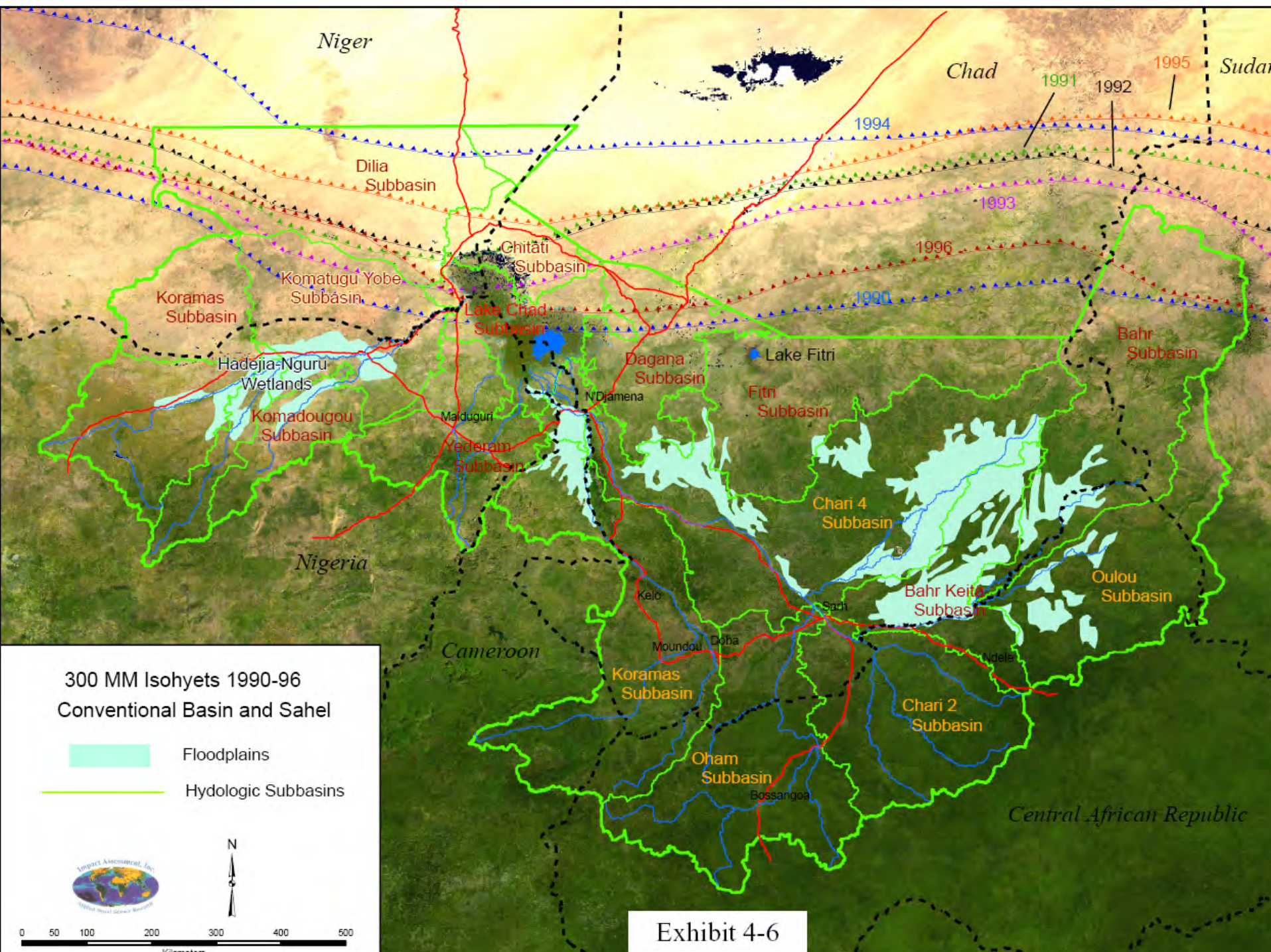

Niger
Chad
Sudan
1991
1992
1995
1994
1993
1996
1990
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Komadougou Subbasin
Yederam Subbasin
Maiduguri
N'Djamena
Dagana Subbasin
Lake Fitri
Fitri Subbasin
Bahr Subbasin
Chari 4 Subbasin
Nigeria
Kelo
Sarh
Bahr Keita Subbasin
Oulou Subbasin
Cameroon
Moundou
Doba
Ndele
Koramas Subbasin
Chari 2 Subbasin
Oham Subbasin
Bossangoa
Central African Republic
300 MM Isohyets 1990-96
Conventional Basin and Sahel
Floodplains
Hydologic Subbasins
N
0 50 100 200 300 400 500

Exhibit 4-6

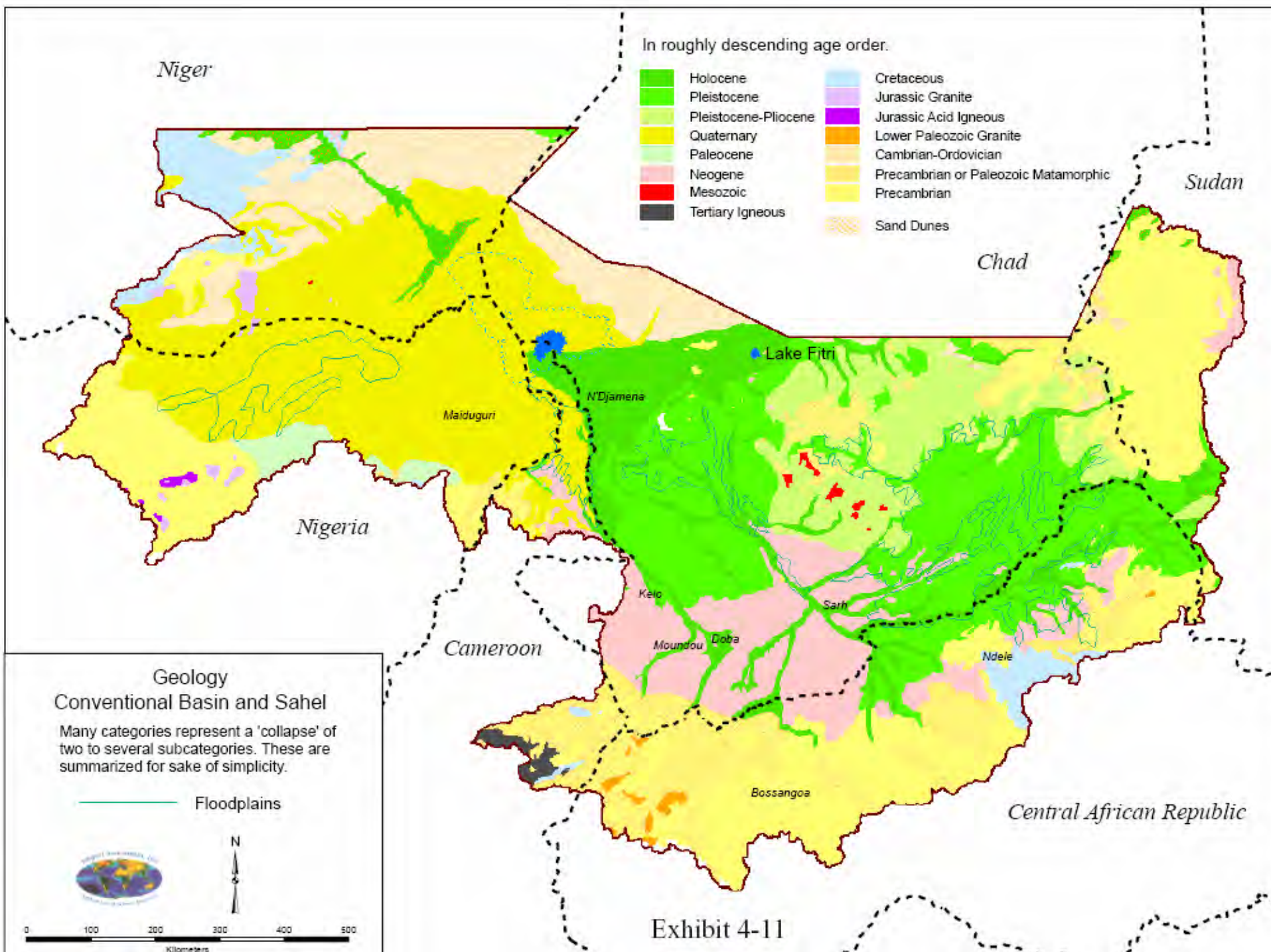

In roughly descending age order.
Holocene
Pleistocene
Pleistocene-Pliocene
Quaternary
Paleocene
Neogene
Mesozoic
Tertiary Igneous
Cretaceous
Jurassic Granite
Jurassic Acid Igneous
Lower Paleozoic Granite
Cambrian-Ordovician
Precambrian or Paleozoic Matamorphic
Precambrian
Sand Dunes
Niger
Sudan
Chad
Lake Fitri
N'Djamena
Maiduguri
Nigeria
Kelo
Sarh
Moundou
Doba
Ndele
Cameroon
Bossangoa
Central African Republic
Geology
Conventional Basin and Sahel
Many categories represent a 'collapse' of two to several subcategories. These are summarized for sake of simplicity.
Floodplains
N
0
100
200
300
400
500
Kilometers

Exhibit 4-11

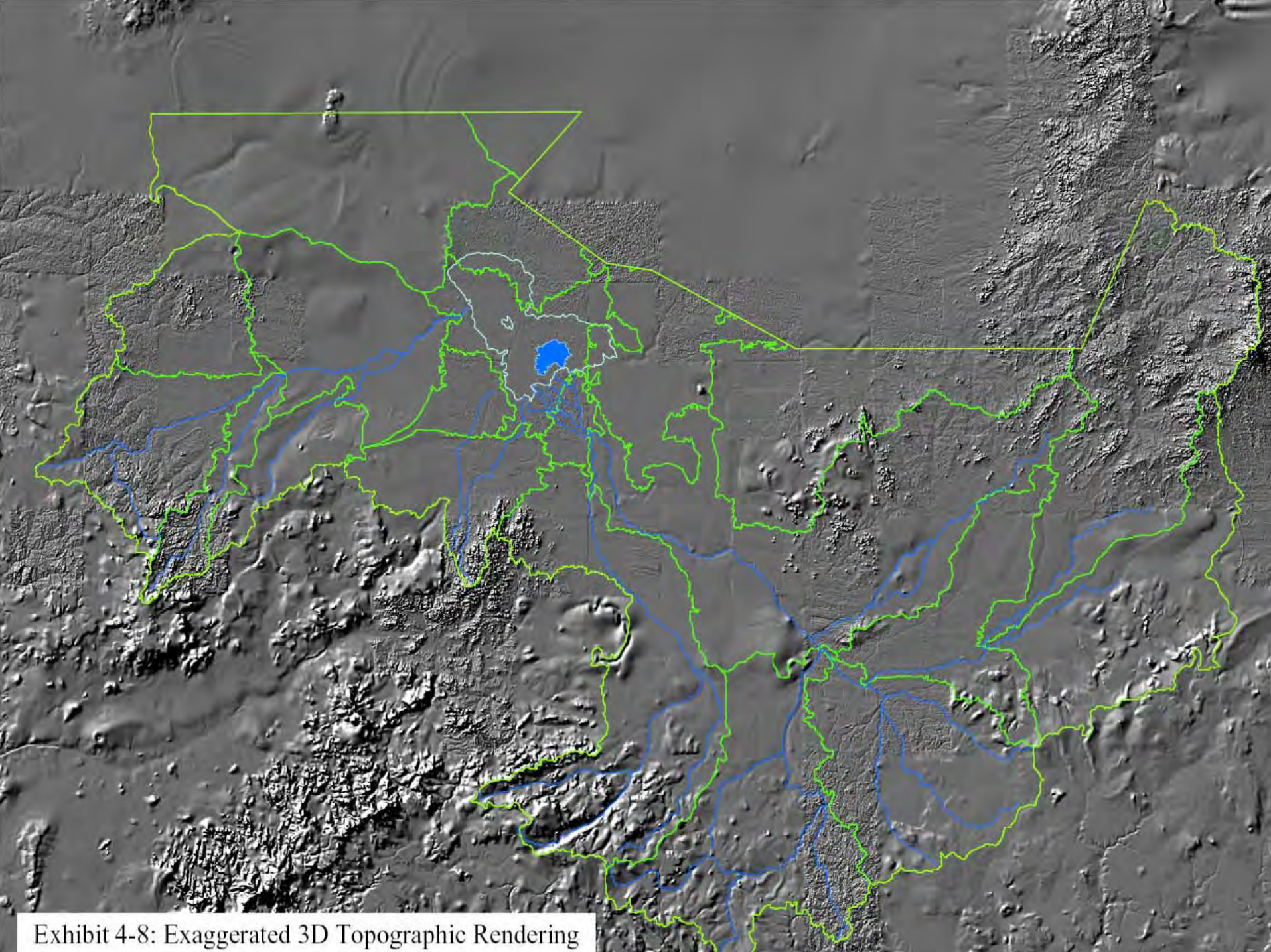


Exhibit 4-8: Exaggerated 3D Topographic Rendering

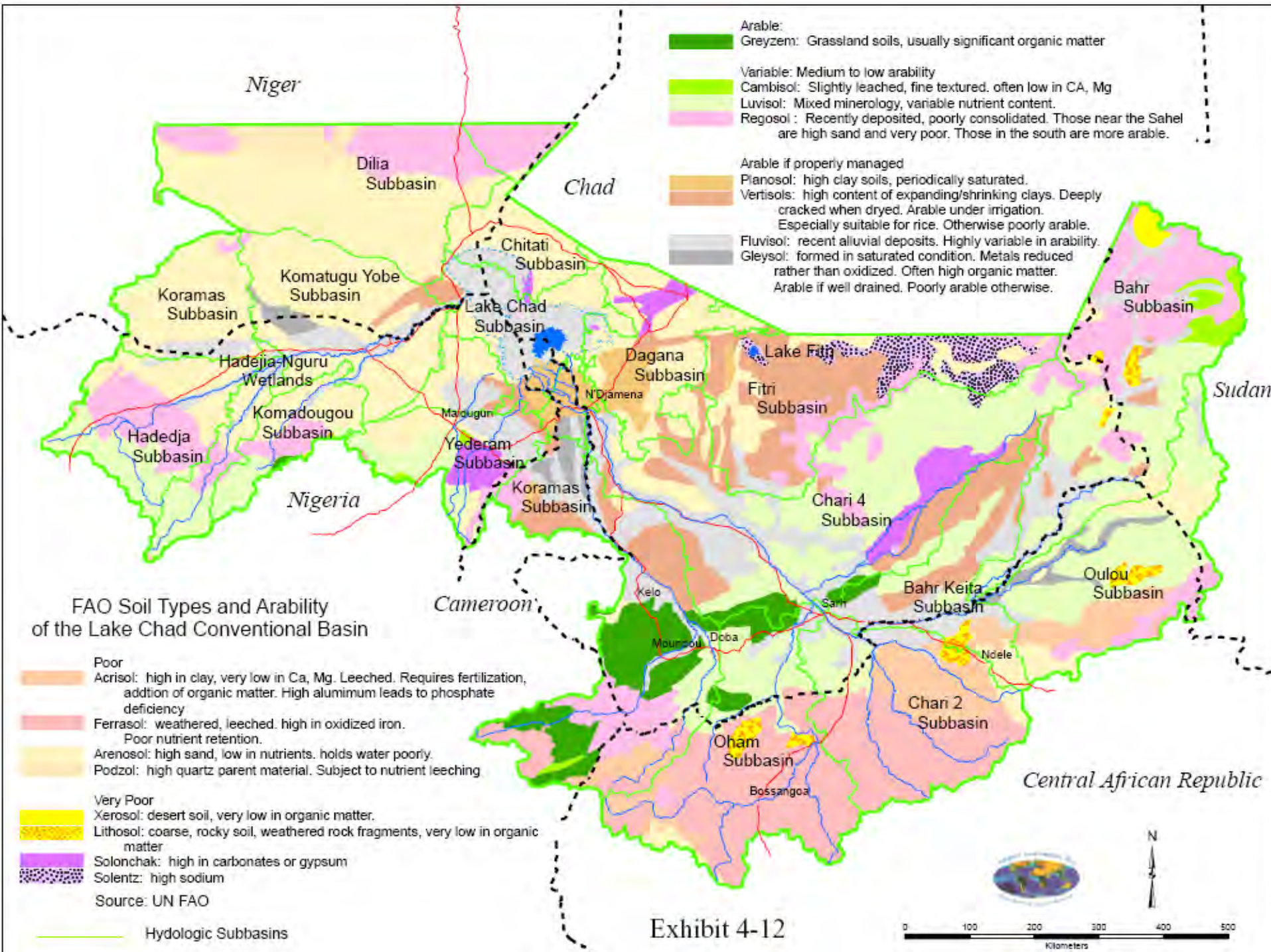

Arable:
Greyzem: Grassland soils, usually significant organic matter
Variable: Medium to low arability
Cambisol: Slightly leached, fine textured. often low in CA, Mg
Luvisol: Mixed minerology, variable nutrient content.
Regosol : Recently deposited, poorly consolidated. Those near the Sahel are high sand and very poor. Those in the south are more arable.
Arable if properly managed
Planosol: high clay soils, periodically saturated.
Vertisols: high content of expanding/shrinking clays. Deeply cracked when dryed. Arable under irrigation. Especially suitable for rice. Otherwise poorly arable.
Fluvisol: recent alluvial deposits. Highly variable in arability.
Gleysol: formed in saturated condition. Metals reduced rather than oxidized. Often high organic matter. Arable if well drained. Poorly arable otherwise.
Niger
Chad
Nigeria
Cameroon
Sudan
Central African Republic
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Komadougou Subbasin
Hadedja Subbasin
Yederam Subbasin
Koramas Subbasin
Dagana Subbasin
Lake Fitri
Fitri Subbasin
Bahr Subbasin
Chari 4 Subbasin
Bahr Keita Subbasin
Oulou Subbasin
Chari 2 Subbasin
Oham Subbasin
N'Djamena
Maiduguri
Kelo
Moundou
Doba
Sarh
Ndele
Bossangoa
FAO Soil Types and Arability of the Lake Chad Conventional Basin
Poor
Acrisol: high in clay, very low in Ca, Mg. Leeched. Requires fertilization, addtion of organic matter. High alumimum leads to phosphate deficiency
Ferrasol: weathered, leeched. high in oxidized iron. Poor nutrient retention.
Arenosol: high sand, low in nutrients. holds water poorly.
Podzol: high quartz parent material. Subject to nutrient leeching
Very Poor
Xerosol: desert soil, very low in organic matter.
Lithosol: coarse, rocky soil, weathered rock fragments, very low in organic matter
Solonchak: high in carbonates or gypsum
Solentz: high sodium
Source: UN FAO
Hydologic Subbasins
N
0 100 200 300 400 500
Kilometers

Exhibit 4-12

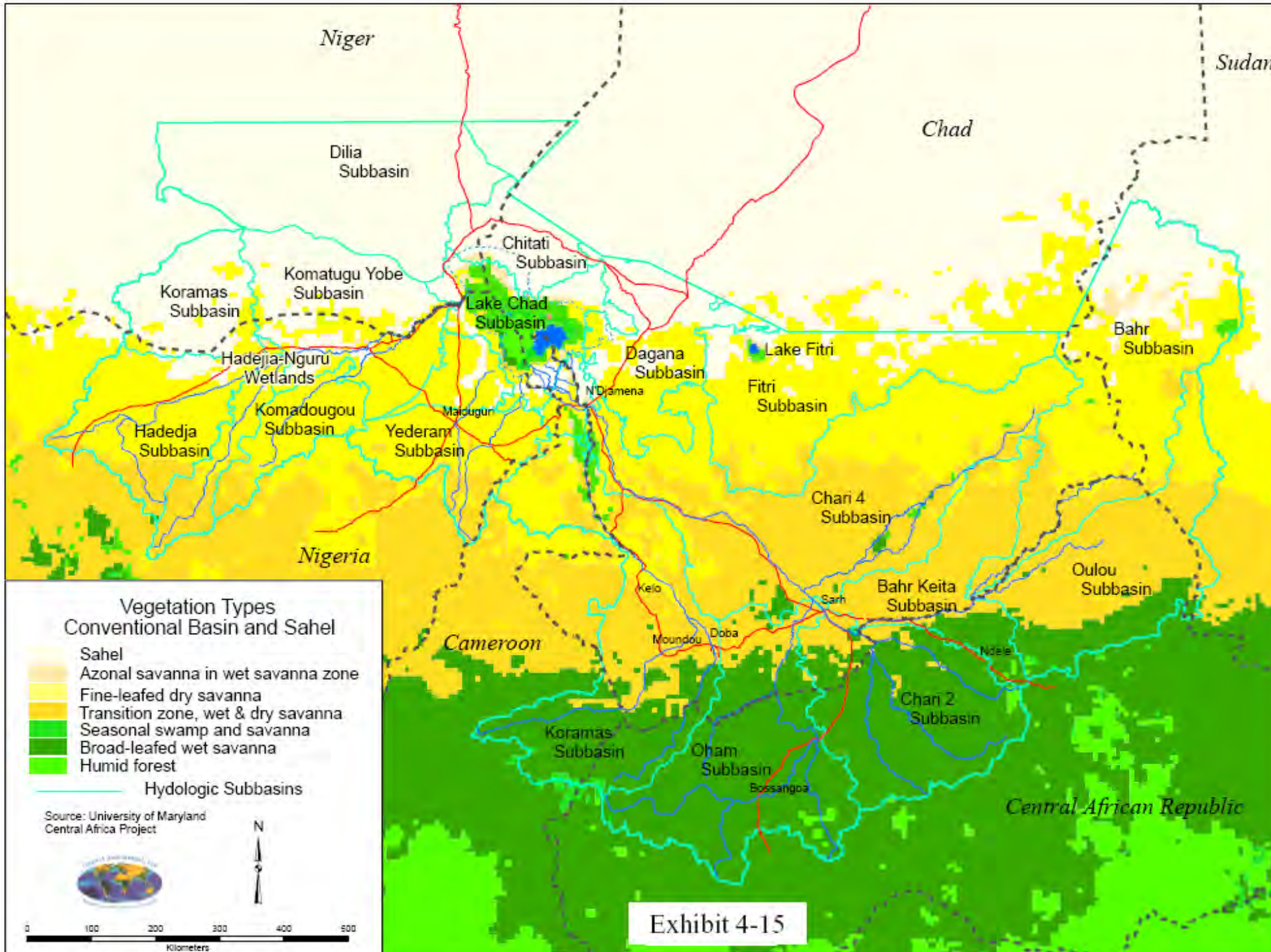
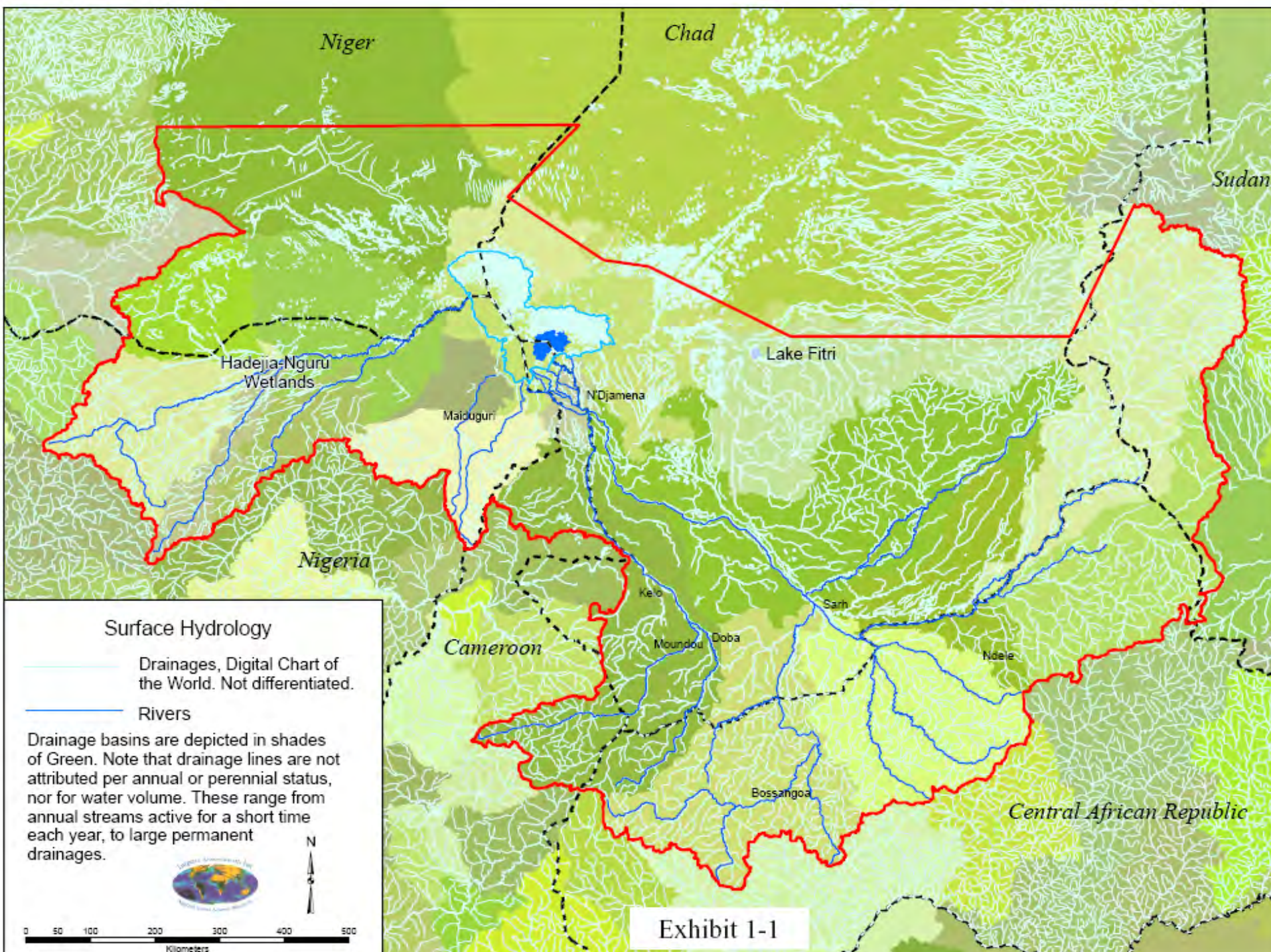
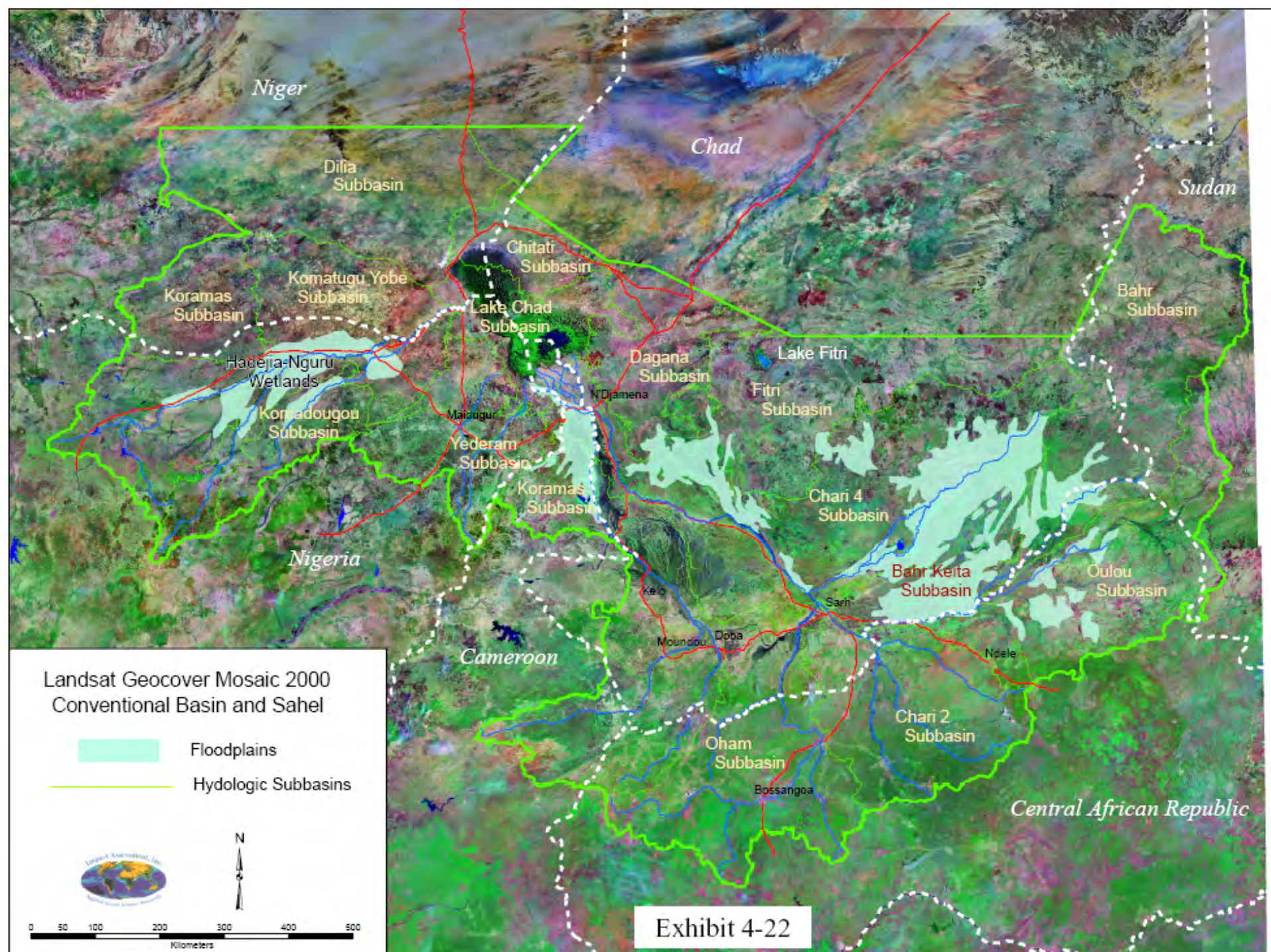

Niger
Chad
Sudan
Nigeria
Cameroon
Central African Republic
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Dagana Subbasin
Lake Fitri
Fitri Subbasin
Bahr Subbasin
N'Djamena
Maiduguri
Komadougou Subbasin
Hadedja Subbasin
Yederam Subbasin
Chari 4 Subbasin
Kelo
Sarh
Bahr Keita Subbasin
Oulou Subbasin
Moundou
Doba
Ndele
Chari 2 Subbasin
Koramas Subbasin
Oham Subbasin
Bossangoa
Vegetation Types
Conventional Basin and Sahel
Sahel
Azonal savanna in wet savanna zone
Fine-leafed dry savanna
Transition zone, wet & dry savanna
Seasonal swamp and savanna
Broad-leafed wet savanna
Humid forest
Hydologic Subbasins
Source: University of Maryland
Central Africa Project
N
0 100 200 300 400 500
Kilometers

Exhibit 4-15


Niger
Chad
Sudan
Lake Fitri
Hadejia-Nguru Wetlands
N'Djamena
Maiduguri
Nigeria
Kelo
Sarh
Cameroon
Moundou
Doba
Ndele
Bossangoa
Central African Republic
Surface Hydrology
Drainages, Digital Chart of the World. Not differentiated.
Rivers
Drainage basins are depicted in shades of Green. Note that drainage lines are not attributed per annual or perennial status, nor for water volume. These range from annual streams active for a short time each year, to large permanent drainages.
N
0 50 100 200 300 400 500
Kilometers
Exhibit 1-1


Niger
Chad
Sudan
Nigeria
Cameroon
Central African Republic
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Komadougou Subbasin
Maiduguri
Yederam Subbasin
Koramas Subbasin
Dagana Subbasin
N'Djamena
Lake Fitri
Fitri Subbasin
Bahr Subbasin
Chari 4 Subbasin
Bahr Keita Subbasin
Oulou Subbasin
Sarh
Kelo
Moundou
Doba
Ndele
Chari 2 Subbasin
Oham Subbasin
Bossangoa
Landsat Geocover Mosaic 2000
Conventional Basin and Sahel
Floodplains
Hydologic Subbasins
N
0 50 100 200 300 400 500
Kilometers
Exhibit 4-22

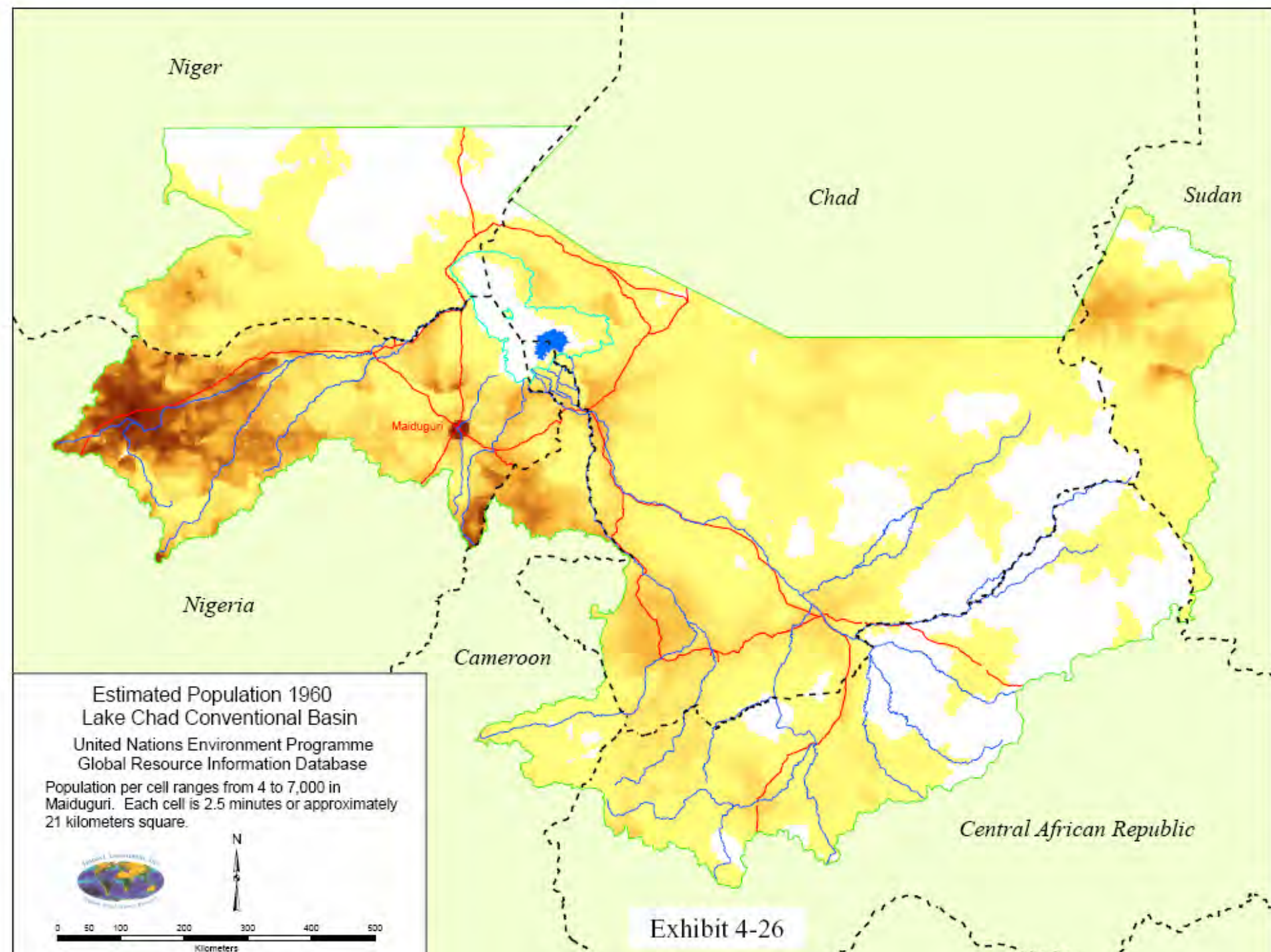

Niger
Chad
Sudan
Maiduguri
Nigeria
Cameroon
Central African Republic
Estimated Population 1960
Lake Chad Conventional Basin
United Nations Environment Programme
Global Resource Information Database
Population per cell ranges from 4 to 7,000 in Maiduguri. Each cell is 2.5 minutes or approximately 21 kilometers square.
N
0 50 100 200 300 400 500
Kilometers

Exhibit 4-26

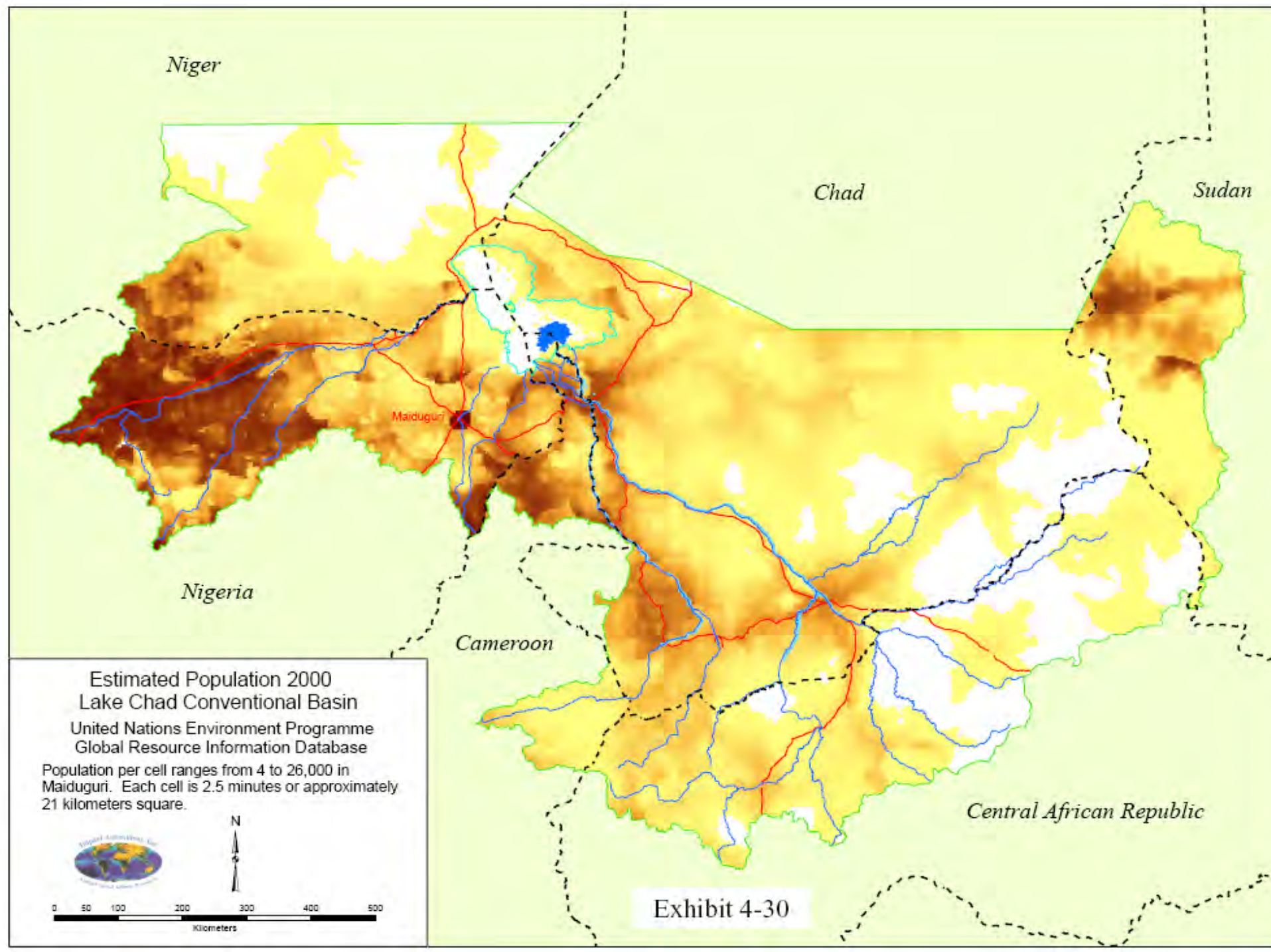

Niger
Chad
Sudan
Maiduguri
Nigeria
Cameroon
Central African Republic
Estimated Population 2000
Lake Chad Conventional Basin
United Nations Environment Programme
Global Resource Information Database
Population per cell ranges from 4 to 26,000 in Maiduguri. Each cell is 2.5 minutes or approximately 21 kilometers square.
N
0 50 100 200 300 400 500
Kilometers

Exhibit 4-30

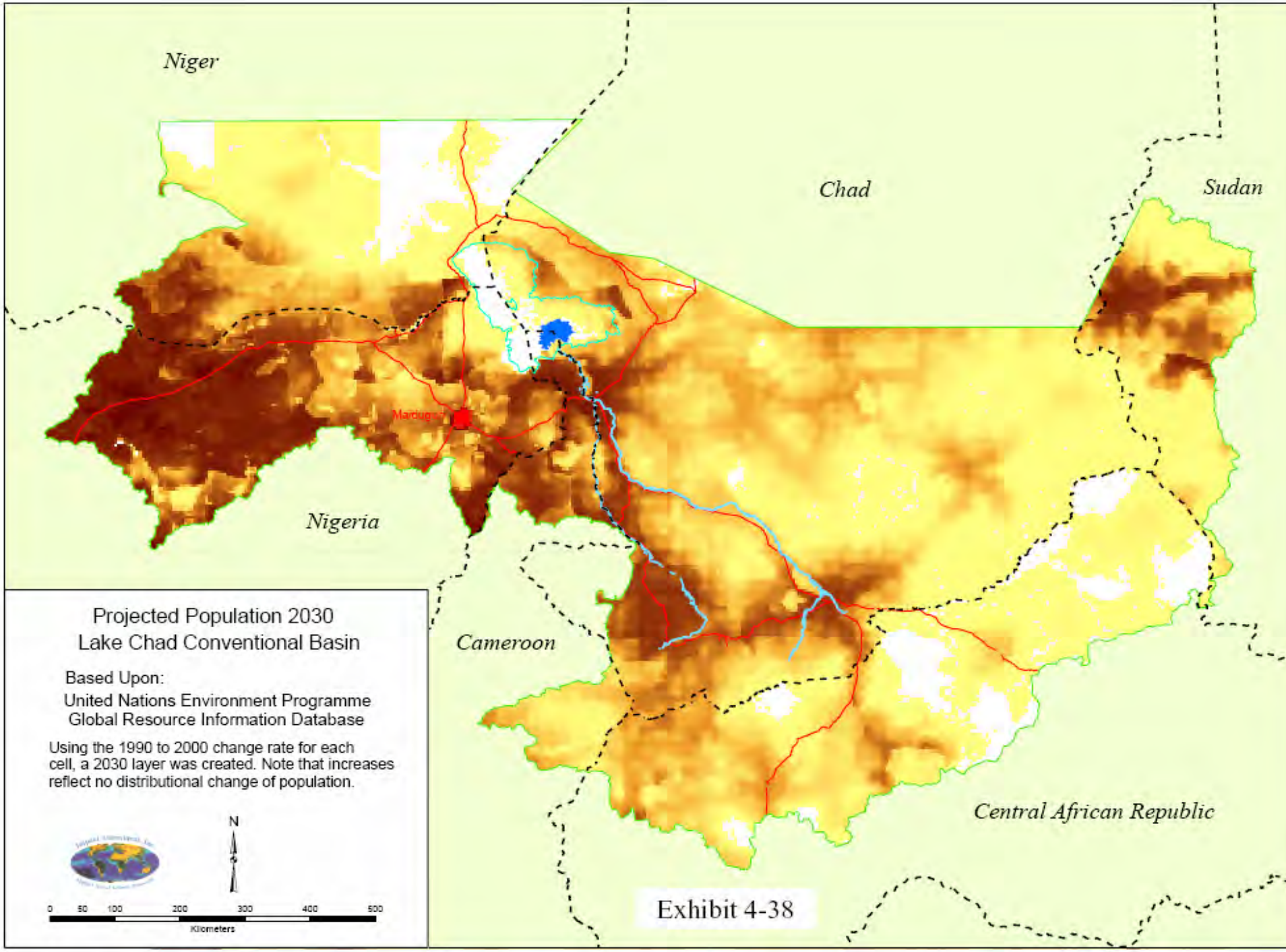

Niger
Chad
Sudan
Maiduguri
Nigeria
Cameroon
Central African Republic
Projected Population 2030
Lake Chad Conventional Basin
Based Upon:
United Nations Environment Programme
Global Resource Information Database
Using the 1990 to 2000 change rate for each cell, a 2030 layer was created. Note that increases reflect no distributional change of population.
N
0 50 100 200 300 400 500
Kilometers

Exhibit 4-38

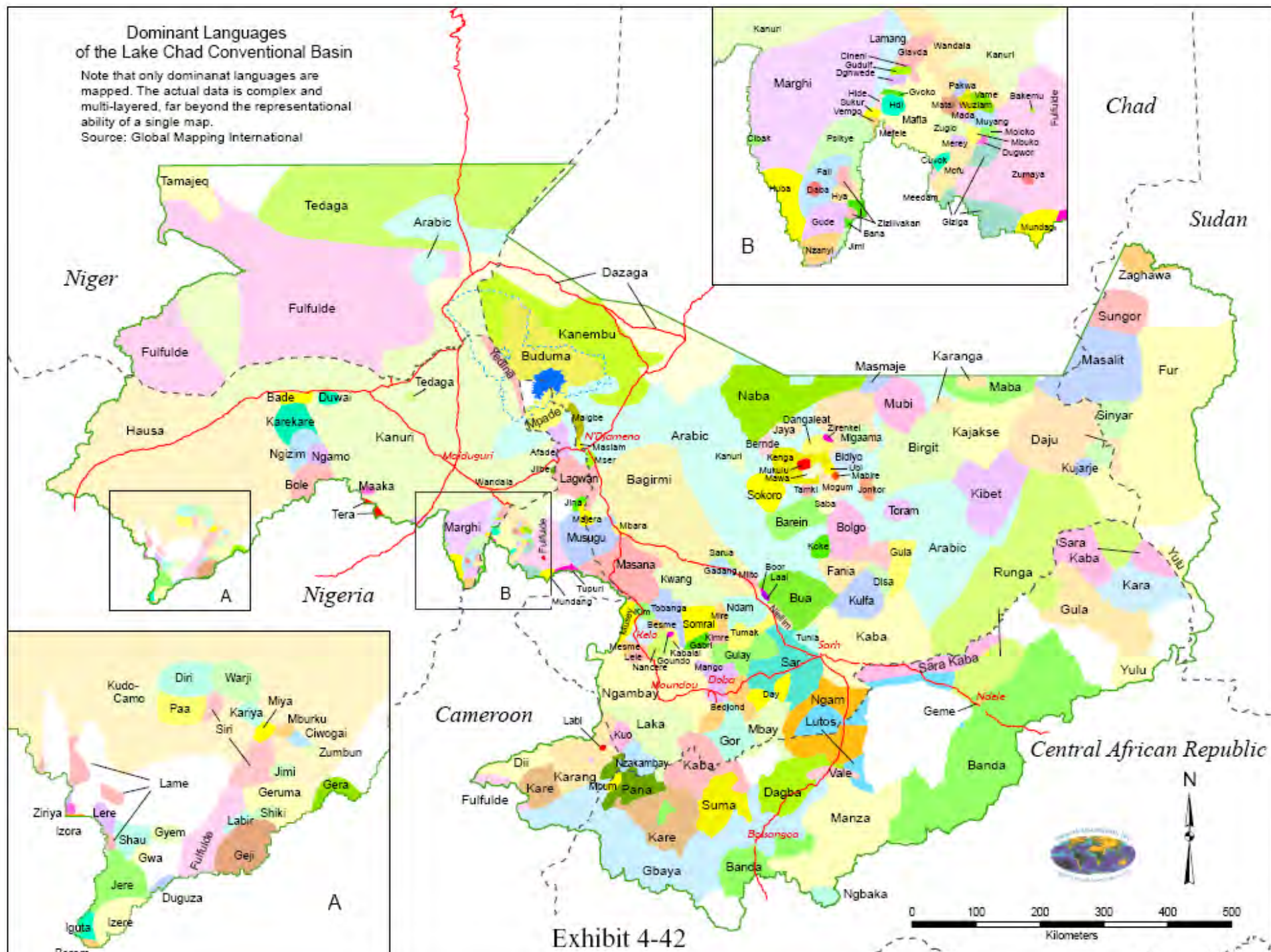
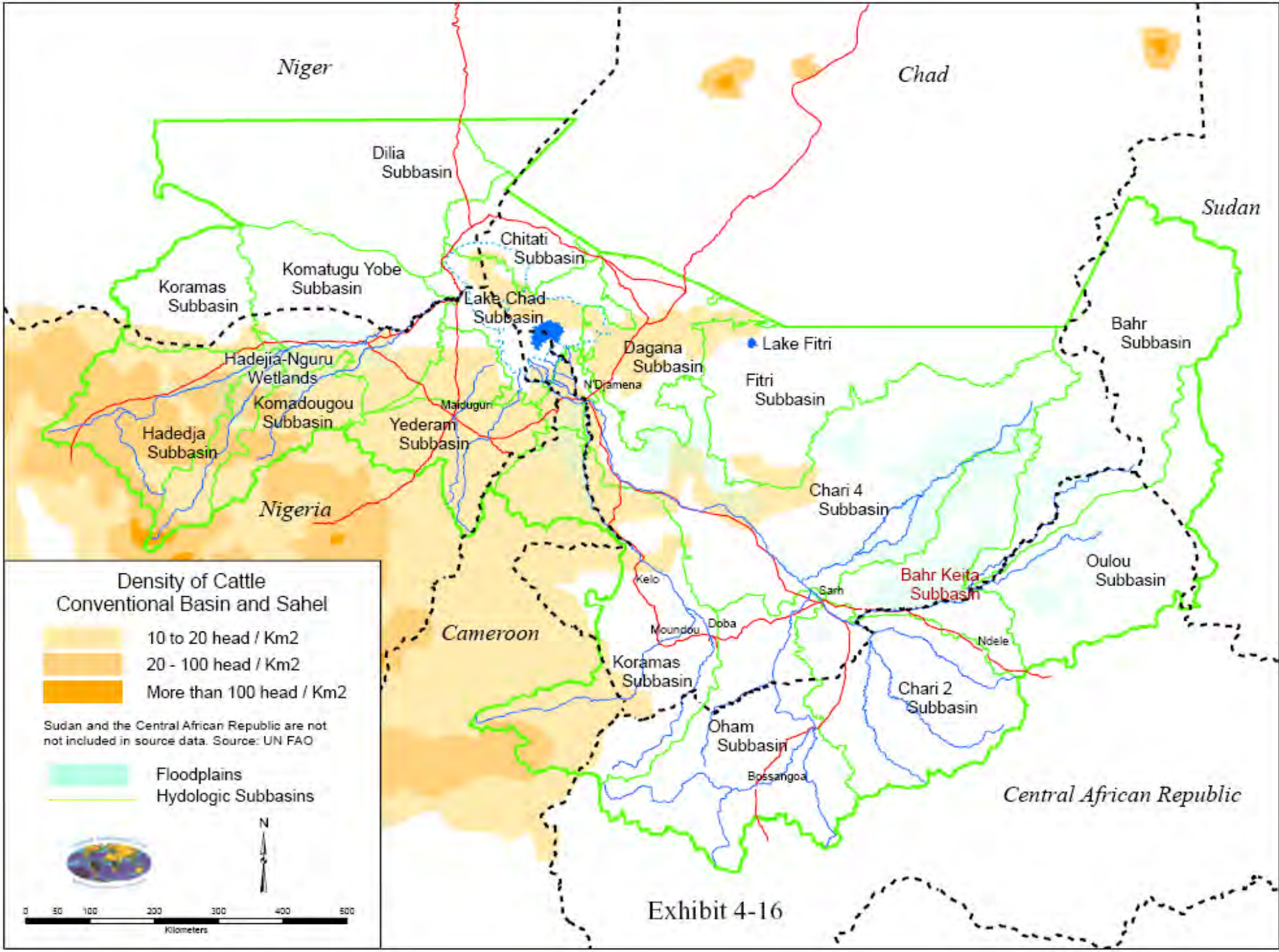
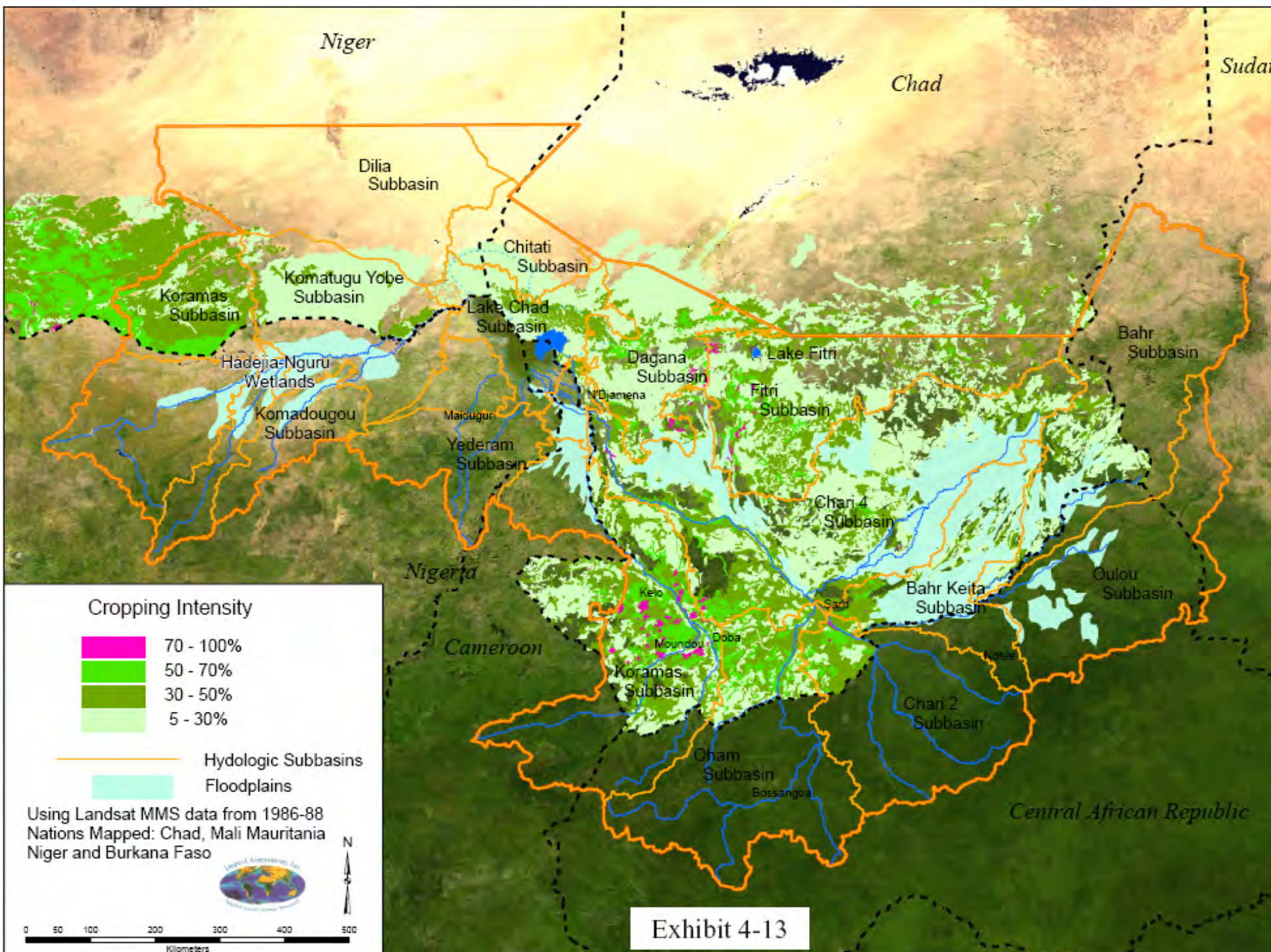
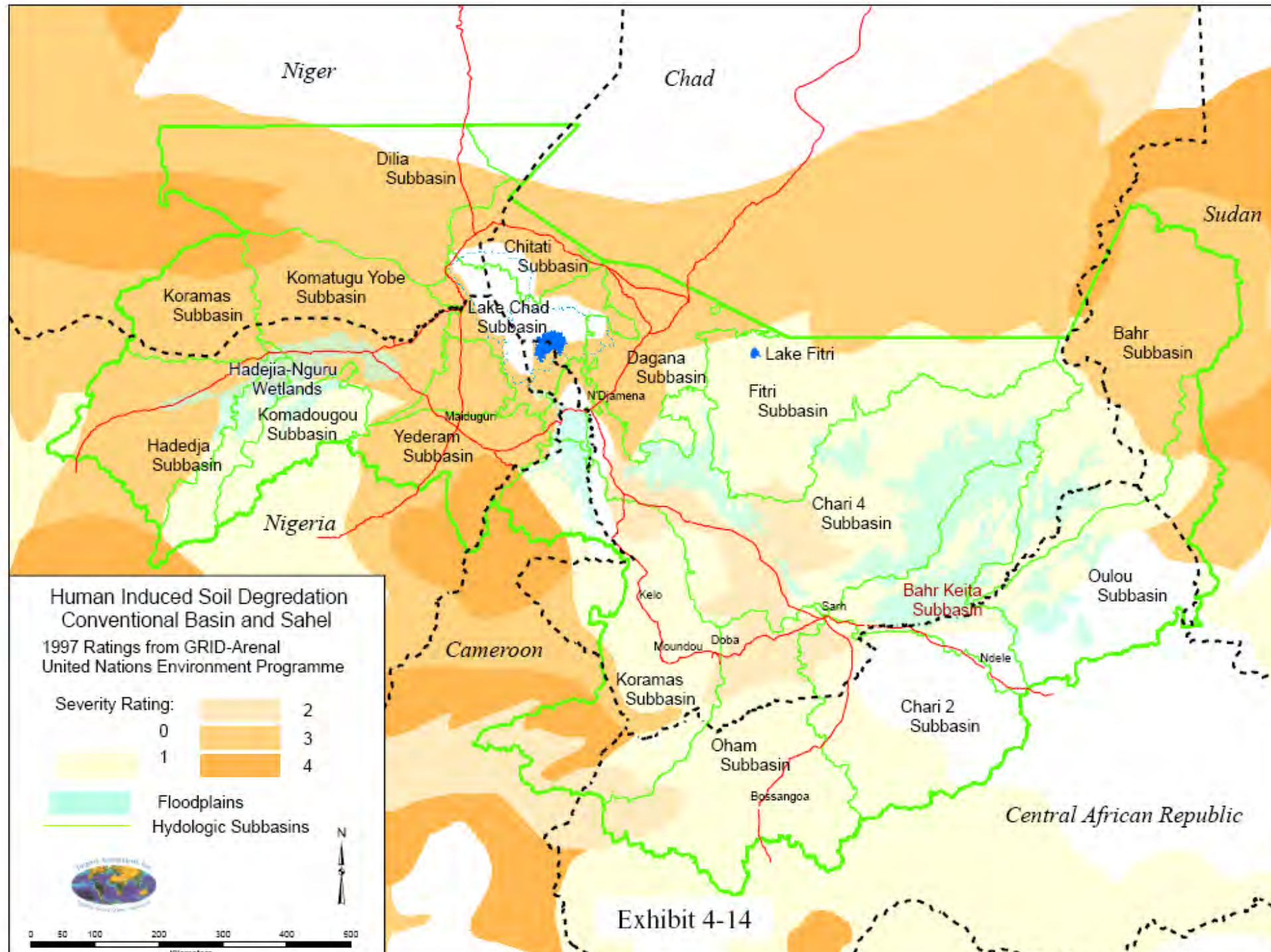
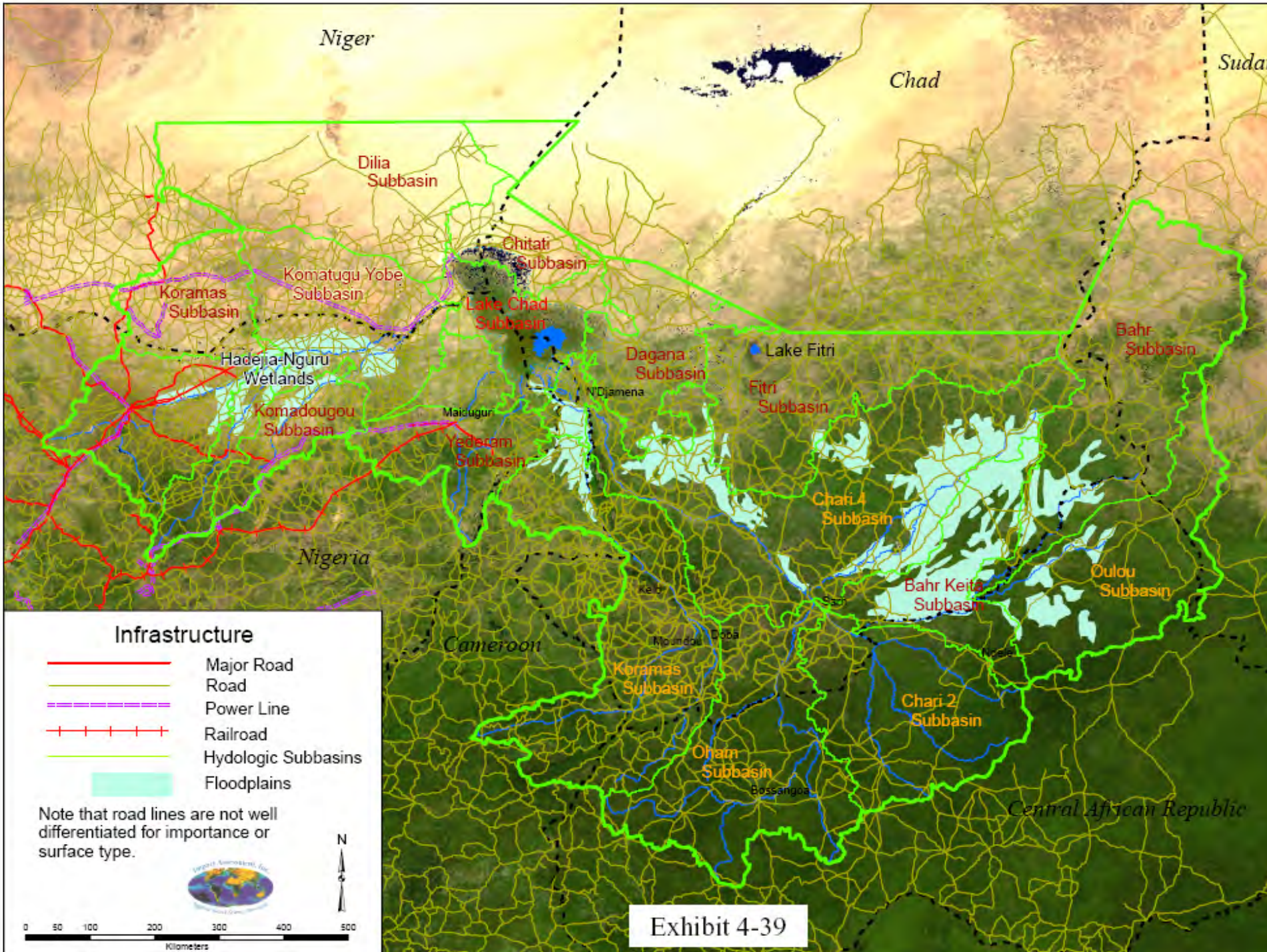

Dominant Languages
of the Lake Chad Conventional Basin
Note that only dominanat languages are mapped. The actual data is complex and multi-layered, far beyond the representational ability of a single map.
Source: Global Mapping International
Niger
Nigeria
Cameroon
Chad
Sudan
Central African Republic
Tamajeq
Tedaga
Arabic
Fulfulde
Dazaga
Kanembu
Buduma
Yedina
Hausa
Bade
Duwai
Karekare
Ngizim
Ngamo
Bole
Maaka
Tera
Kanuri
Maiduguri
Afadei
Jibeli
Wandala
Lagwan
Mpade
Maigbe
N'Djamena
Maslam
Mser
Jina
Mbera
Musugu
Marghi
Fulfulde
Tupuri
Mundang
Bagirmi
Sanua
Masana
Kwang
Gadang
Mbo
Boor
Laal
Bua
Kulfa
Fania
Disa
Runga
Kaba
Kara
Gula
Yulu
Sara Kaba
Sara
Naba
Masmaje
Karanga
Maba
Mubi
Dangaleat
Jaya
Zirenkel
Migaama
Bernde
Kenga
Bidlyo
Mukulu
Mawa
Uci
Mabire
Tamki
Mogum
Jonkor
Sokoro
Saba
Barein
Bolgo
Koke
Toram
Kibet
Birgit
Kajakse
Daju
Kujarje
Sinyar
Masalit
Fur
Zaghawa
Sungor
Arabic
Gula
Tobanga
Ndam
Mire
Besme
Somral
Kelo
Tumak
Kimre
Gabri
Kabalai
Gulay
Mesme
Lele
Nancere
Goundo
Mango
Tunia
Sorh
Kaba
Sar
Moundou
Doba
Day
Bedjond
Ngambay
Ngam
Lutos
Mbay
Gor
Laka
Labi
Kuo
Nzakambay
Kaba
Dii
Karang
Kare
Mum
Pana
Fulfulde
Suma
Dagba
Vale
Manza
Banda
Kare
Bolsongoo
Gbaya
Banda
Ngbaka
Geme
Ndele
Lamang
Gisiga
Wandala
Kanuri
Cineni
Gudulf
Dghwede
Marghi
Hide
Gvoko
Pakwa
Vame
Bakemu
Sukur
Vemgo
Hdi
Matal
Wuzlam
Mafla
Mada
Muyang
Zugio
Mofako
Mbuko
Dugwor
Mefele
Merey
Cuvok
Mofu
Zumaya
Fali
Huba
Daba
Hya
Meedam
Gude
Zizilivakan
Bana
Jimi
Nzanyi
Mundaga
B
Kudo-
Camo
Diri
Warji
Paa
Kariya
Miya
Siri
Mburku
Ciwogai
Zumbun
Jimi
Lame
Geruma
Gera
Ziriya
Lere
Izora
Shiki
Labir
Shau
Gyem
Gwa
Geji
Fulfulde
Jere
Duguza
Iguta
Izere
A
0
100
200
300
400
500
Kilometers
N

Exhibit 4-42


Niger
Chad
Sudan
Nigeria
Cameroon
Central African Republic
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Dagana Subbasin
Lake Fitri
Fitri Subbasin
Bahr Subbasin
Hadejia-Nguru Wetlands
Komadougou Subbasin
Hadedja Subbasin
Yederam Subbasin
N'Djamena
Maiduguri
Chari 4 Subbasin
Oulou Subbasin
Bahr Keita Subbasin
Kelo
Sarh
Moundou
Doba
Ndele
Koramas Subbasin
Chari 2 Subbasin
Oham Subbasin
Bossangoa
Density of Cattle
Conventional Basin and Sahel
10 to 20 head / Km2
20 - 100 head / Km2
More than 100 head / Km2
Sudan and the Central African Republic are not not included in source data. Source: UN FAO
Floodplains
Hydologic Subbasins
N
0 50 100 200 300 400 500
Kilometers
Exhibit 4-16


Niger
Chad
Suda
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Komadougou Subbasin
Maiduguri
Yederam Subbasin
N'Djamena
Dagana Subbasin
Lake Fitri
Fitri Subbasin
Bahr Subbasin
Chari 4 Subbasin
Nigeria
Kelo
Sadi
Bahr Keita Subbasin
Oulou Subbasin
Cameroon
Moundou
Doba
Koramas Subbasin
Chari 2 Subbasin
Oham Subbasin
Bossangoa
Central African Republic
Cropping Intensity
70 - 100%
50 - 70%
30 - 50%
5 - 30%
Hydologic Subbasins
Floodplains
Using Landsat MMS data from 1986-88
Nations Mapped: Chad, Mali Mauritania
Niger and Burkana Faso
N
0 50 100 200 300 400 500
Kilometers
Exhibit 4-13


Niger
Chad
Sudan
Nigeria
Cameroon
Central African Republic
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Komadougou Subbasin
Hadedja Subbasin
Yederam Subbasin
Maiduguri
N'Djamena
Dagana Subbasin
Lake Fitri
Fitri Subbasin
Bahr Subbasin
Chari 4 Subbasin
Bahr Keita Subbasin
Oulou Subbasin
Kelo
Sarh
Moundou
Doba
Ndele
Koramas Subbasin
Chari 2 Subbasin
Oham Subbasin
Bossangoa
Human Induced Soil Degredation
Conventional Basin and Sahel
1997 Ratings from GRID-Arenal
United Nations Environment Programme
Severity Rating:
0
1
2
3
4
Floodplains
Hydologic Subbasins
N
0 50 100 200 300 400 500
Exhibit 4-14


Niger
Chad
Suda
Dilia Subbasin
Chitati Subbasin
Komatugu Yobe Subbasin
Koramas Subbasin
Lake Chad Subbasin
Hadejia-Nguru Wetlands
Dagana Subbasin
Lake Fitri
Bahr Subbasin
N'Djamena
Fitri Subbasin
Maiduguri
Komadougou Subbasin
Yedseram Subbasin
Chari 1 Subbasin
Nigeria
Oulou Subbasin
Bahr Keita Subbasin
Sarh
Cameroon
Koramas Subbasin
Chari 2 Subbasin
Oham Subbasin
Bossangoa
Central African Republic
Infrastructure
Major Road
Road
Power Line
Railroad
Hydologic Subbasins
Floodplains
Note that road lines are not well differentiated for importance or surface type.
N
0 50 100 200 300 400 500
Kilometers
Exhibit 4-39

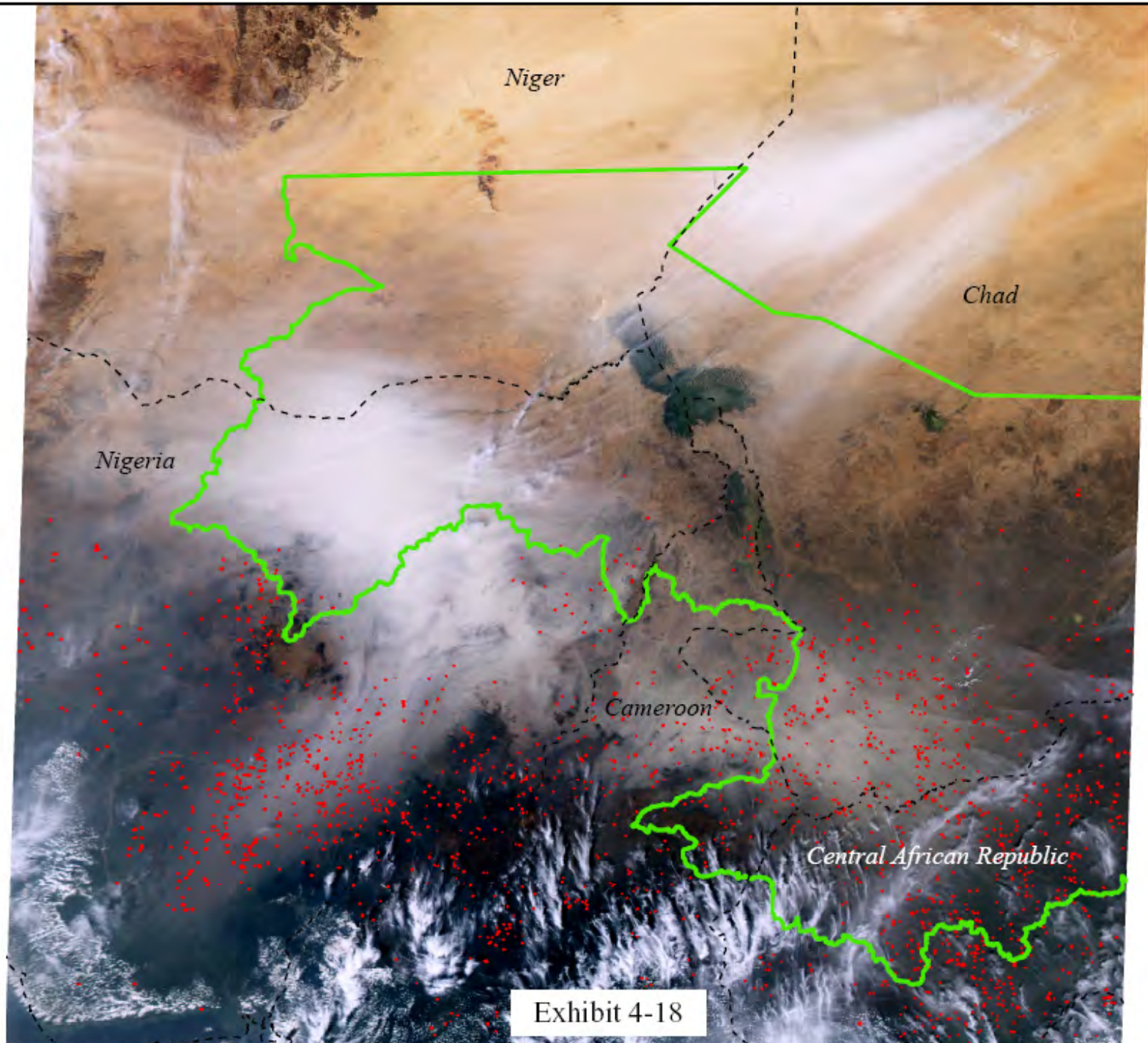


Exhibit 4-18

Lake Chad Basin (UNDP)

- **Ecosystem Impacts of Rapid Rainfall Decline:**
  - Rapid collapse of lake ecosystems as lake recedes
  - Increased salinity (favoring species adapted to water stress)
  - Annual grasses replacing perennial grasses (invasive species, Typha grasses)
  - Declining plant biodiversity, absolute decline in total vegetative cover
  - Declining animal, avian and fishery diversity, increased fish mortality, loss of spawning beds, shift in the distribution of copepods, principal fish species, and depression of planktivorous pelagic freshwater fisheries
  - Increased erosion processes, desertification

Lake Chad Basin (UNDP)

- **Anthropogenic Contributions**
  - Massive population increase (humans, increasingly, live in urban environments, exposed to urban risks)
  - Massive water mismanagement (dams, irrigation, distribution disparities)
  - Massive acceleration of erosion processes, groundwater recession, desertification, pollution, debris
- **Health Consequences of Climate Change and Human Behavior**
  - Contaminated water resources
  - Declining wild and domestic plant/animal species abundance – diet and health
  - Direct impacts on food security (starvation)
  - Direct impacts on human health (e.g., the surge in diarrhea, cholera and typhoid fever throughout the basin – infectious disease, injuries, mortality, morbidity)

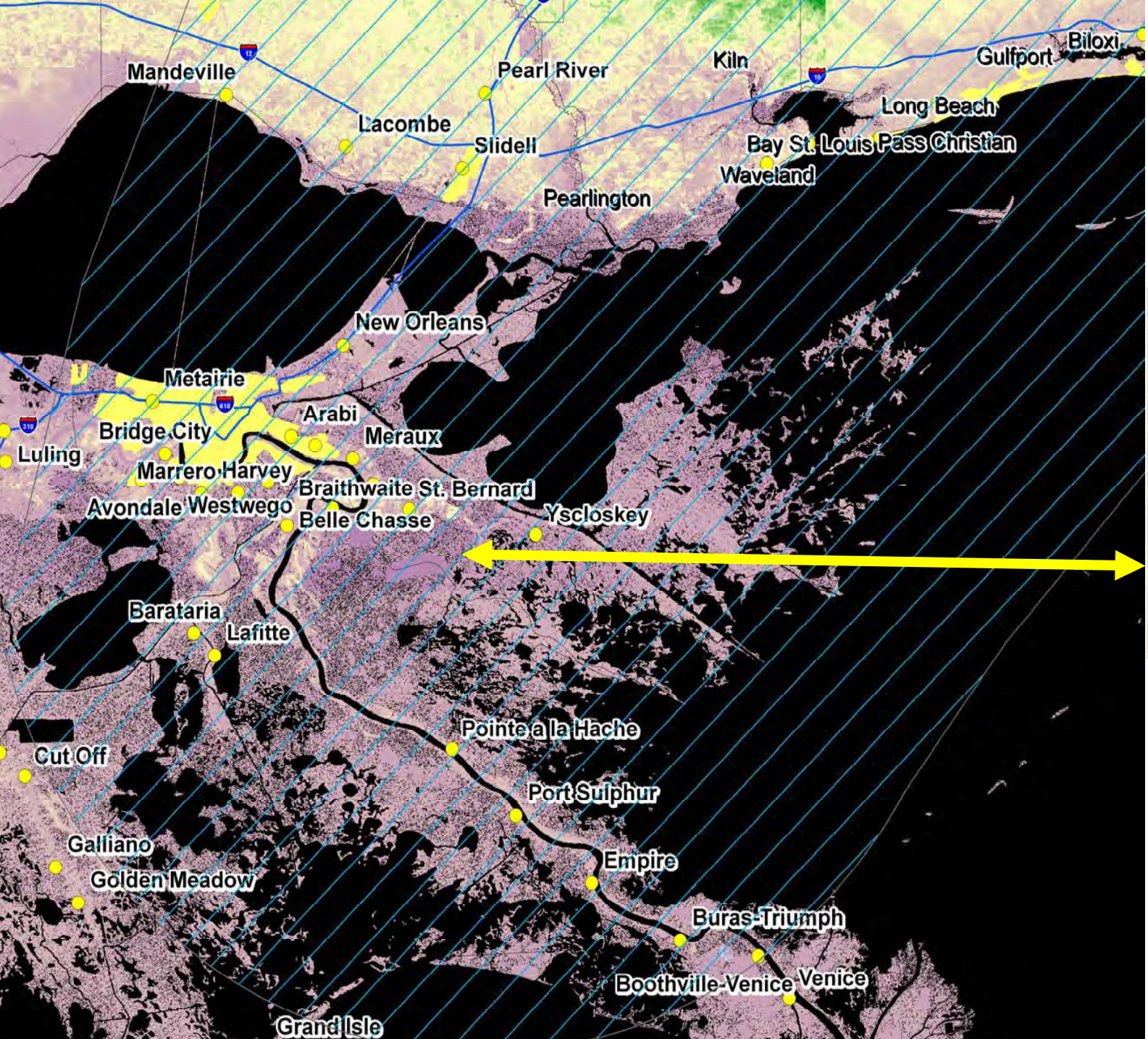
Hurricane Katrina

Hurricane Katrina at Louisiana Coast

(*Landfall: 29 Aug 05, 6:10 am, 145 mph, Category 4*)

Hurricane Katrina Impact Assessment (NOAA)

- **Study objectives:**
  - **Highly-focused in-depth examination of the immediate and short-term social and economic impacts experienced during the initial months following the hurricane (coastal Louisiana, Alabama, and Mississippi);**
  - **Documentation of the *major* financial, material, technical, and logistical impediments to recovery; and**
  - **Coherent analysis of the prospects for recovery – identifying successful and less-successful methods and approaches across the various industry sectors and services, and demographic populations.**


Mandeville
Pearl River
Kiln
Gulfport
Biloxi
Lacombe
Slidell
Long Beach
Bay St. Louis
Pass Christian
Waveland
Pearlington
New Orleans
Metairie
Arabi
Bridge City
Meraux
Luling
Marrero
Harvey
Braithwaite
St. Bernard
Avondale
Westwego
Belle Chasse
Ysclosky
Barataria
Lafitte
Pointe a la Hache
Cut Off
Port Sulphur
Galliano
Empire
Golden Meadow
Buras-Triumph
Boothville-Venice
Venice
Grand Isle
Louisiana Coast
Mean Sea Level
Above 30 Feet
26 - 30 Feet
21 - 25 Feet
16 - 20 Feet
11 - 15 Feet
6 - 10 Feet
1 - 5 Feet
0 or Lower

Coastal Erosion

- Massive Erosion
  - Leveeing and draining has resulted in substantial subsidence over the decades.
  - Most of New Orleans is below sea level (max. deflation is 13 feet)
  - The floods were caused when the levees, with a maximum design capacity of Category 3, were overtopped and breached, causing complete flooding of New Orleans basin.
  - Impact of disaster was much greater because of loss of storm-buffering protection by wetlands and barrier islands.
  - This persistent increase in open water conditions resulted in increased storm surge levels.
  - For the above reasons, Louisiana is probably at a greater risk from hurricanes and other flooding events than at any other time, or any other state.

Coastal Erosion

Southern Louisiana

(NOAA, Aug. 27, 2005)

Southern Louisiana

(NOAA, Aug. 31, 2005)


Runoff
New Orleans (*true color*)
NOAA: Aug. 31, 2005
Main Breach
17th St
London Ave. Breach
Industrial Canal Breach
Flood
Fire

Oil/Chemical Contamination
NOAA: Aug. 31, 2005

Immediate Health Risks

- Potable water (paramount, pervasive water system failure, short-term delivery system overpowered, no power to boil, and no means of disinfecting water, hygiene impossible)
- Food safety (no electricity, refrigerators, microwaves, ovens)
- Portable power system risks (carbon monoxide in confined spaces, downed electrical wire, circuit breaker, water-soaked walls and connectors, other electrocution hazards, associated fire risks)
- Physical hazards (debris, debris, debris, hazardous chemicals, pesticides, industrial wastes everywhere, unexpected locations, cannot rely on past experience)
- Flood water exposure, waterborne disease exposures, human waste, sewage, hazardous waste, contaminated carpets, drapes, soil, dust – everything has been exposed to everything – children and household pets at high risk.

Continuing Health Risks

- **Exposures (mold, dust, Mosquitos/West Nile, spiders, infections, diarrhea, asthma triggers, and in developing countries, cholera, typhoid, malaria)**
- **Persistent cleanup hazards, “like working at a waste dump” for weeks and months, in high-temperature, high-humidity environment.**
- **Pronounced psychological impacts, PTSD, persistent triggers for mental illnesses, impacts on children potentially profound and long-term.**

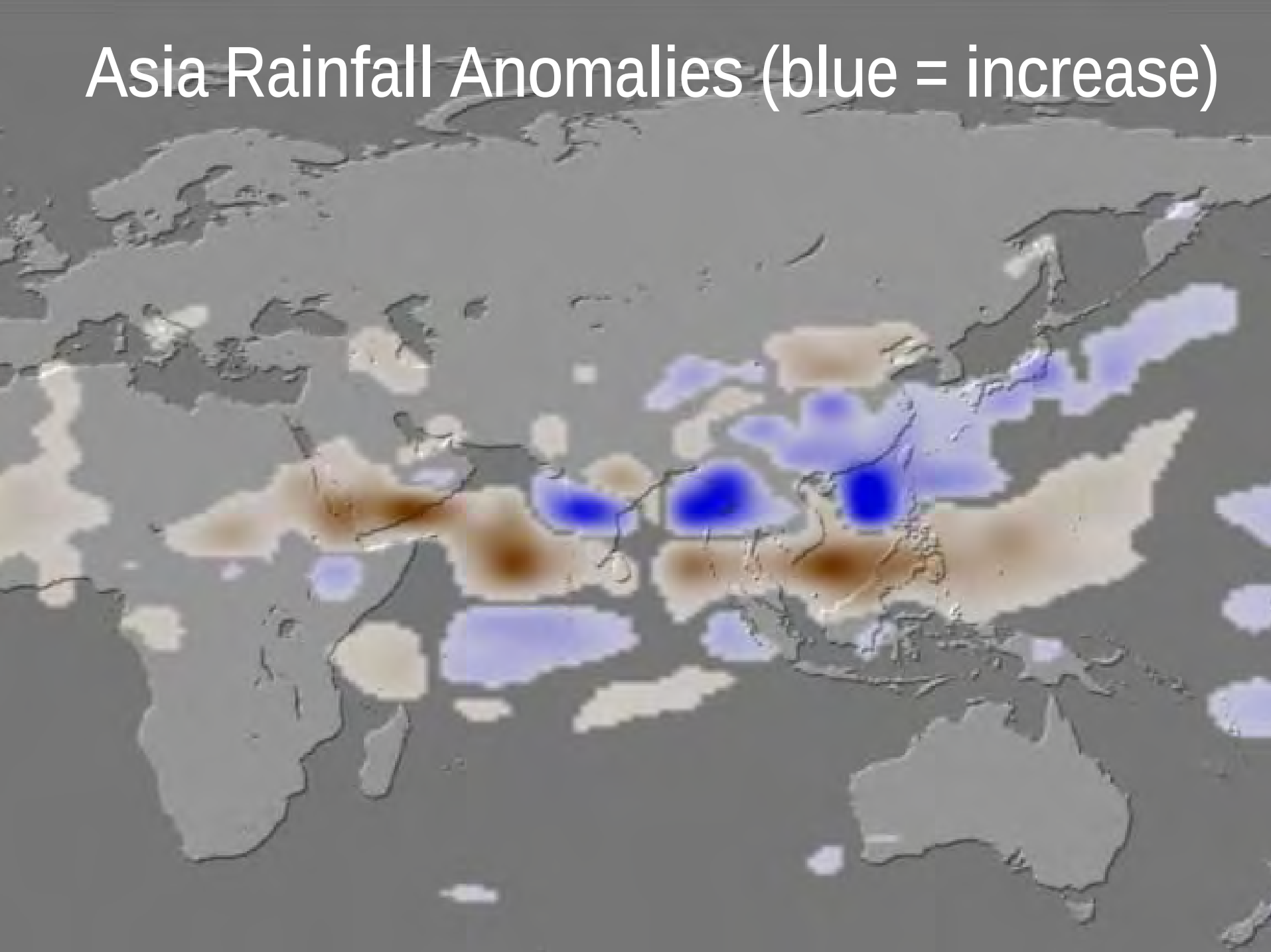
Global Climate Change and Human Health: China

- **Study objectives:**
  - Identify the mechanisms by which global climate change, of anthropogenic origin, primarily in the form of planetary temperature increases, affects China's weather patterns;
  - Characterize how these changes in weather patterns, in turn, give rise to both chronic and acute, and direct and indirect, effects on human disease, disability, and death; and
  - Illuminate how these human health effects have been, and will be, distributed according to existing and growing social vulnerabilities.

Alteration of Regional Weather Patterns

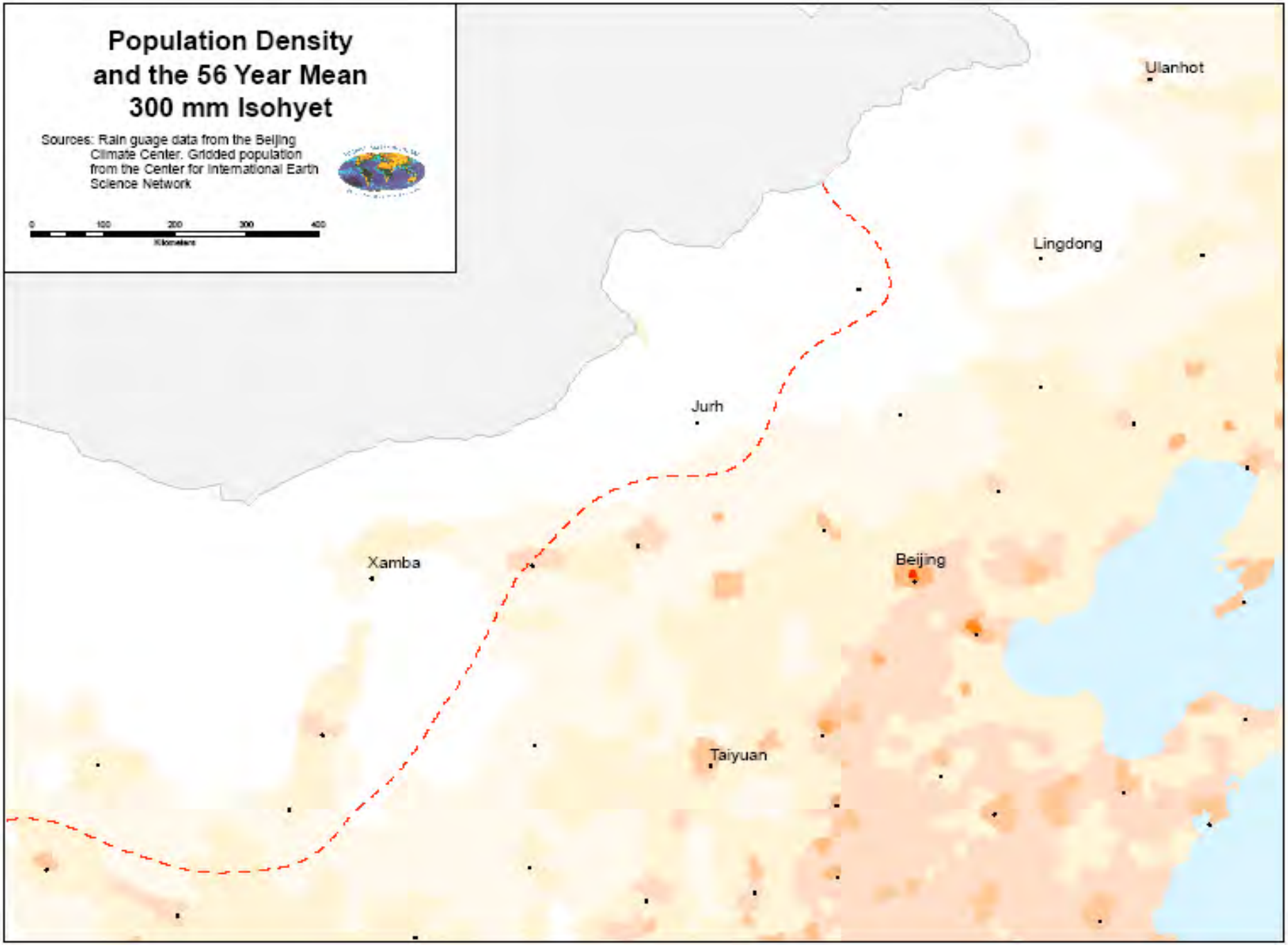
- **Terrestrial**
  - **Altered distribution of rainfall**
  - **Altered timing (initial rains, pattern disruptions, early/late final rainfall)**
  - **Altered agricultural patterns**
  - **Altered natural habitats**
  - **Creation of land no longer suitable for productive use (desertification) due to shifting isotherms and isohyets**

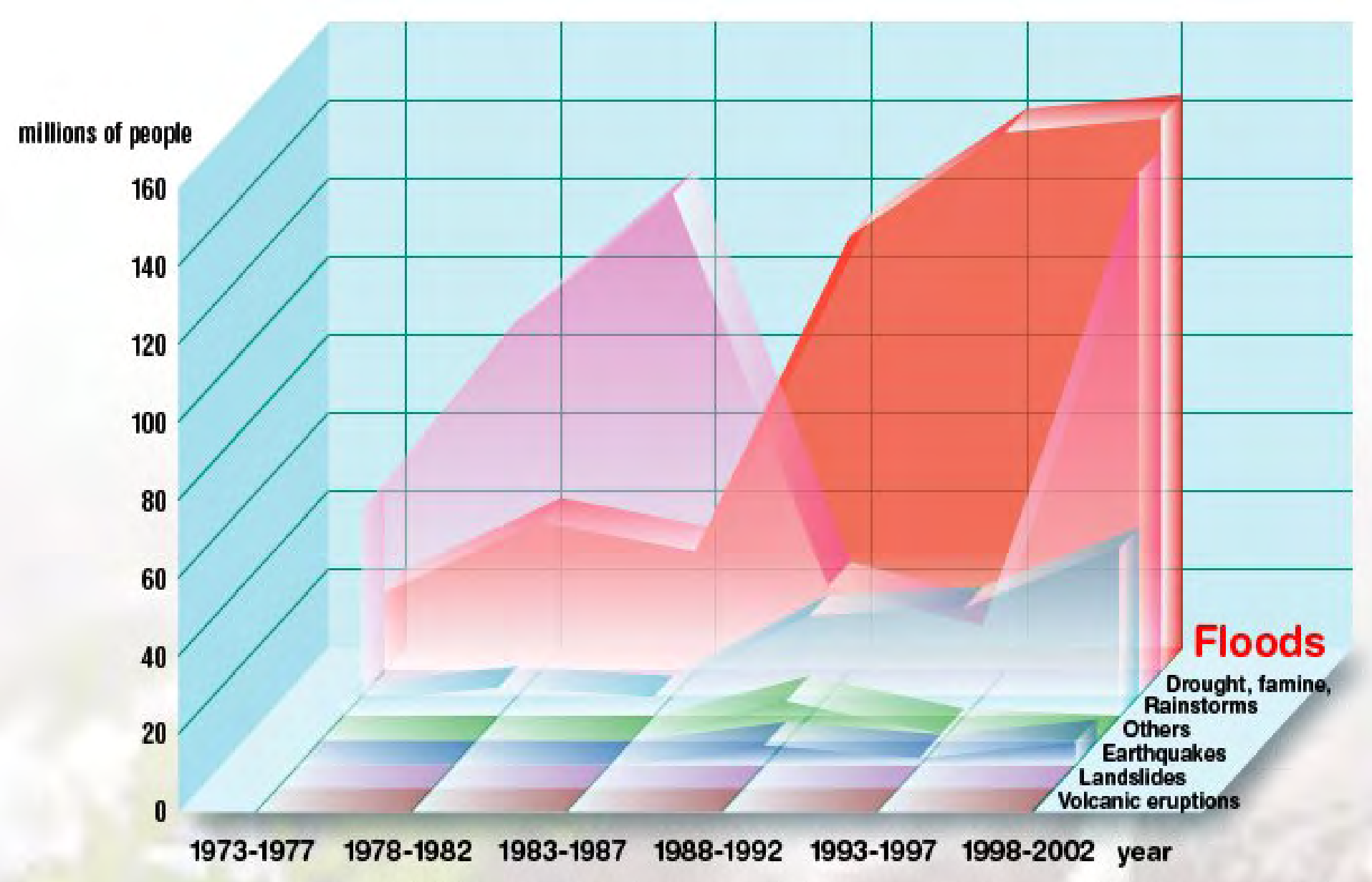
Asia Rainfall Anomalies (blue = increase)



Alteration of Regional Weather Patterns

- Rain
  - Location
  - Early / Late
  - Interrupted
  - Volume/Severity
  - Timing/Frequency
  - Retention
- Floods (anticipated)
- Drought
- Severe events (storms/typhoons)


Population Density
and the 56 Year Mean
300 mm Isohyet
Sources: Rain guage data from the Beijing
Climate Center. Gridded population
from the Center for International Earth
Science Network
0
100
200
300
400
Kilometers
Ulanhot
Lingdong
Jurh
Xamba
Beijing
Taiyuan



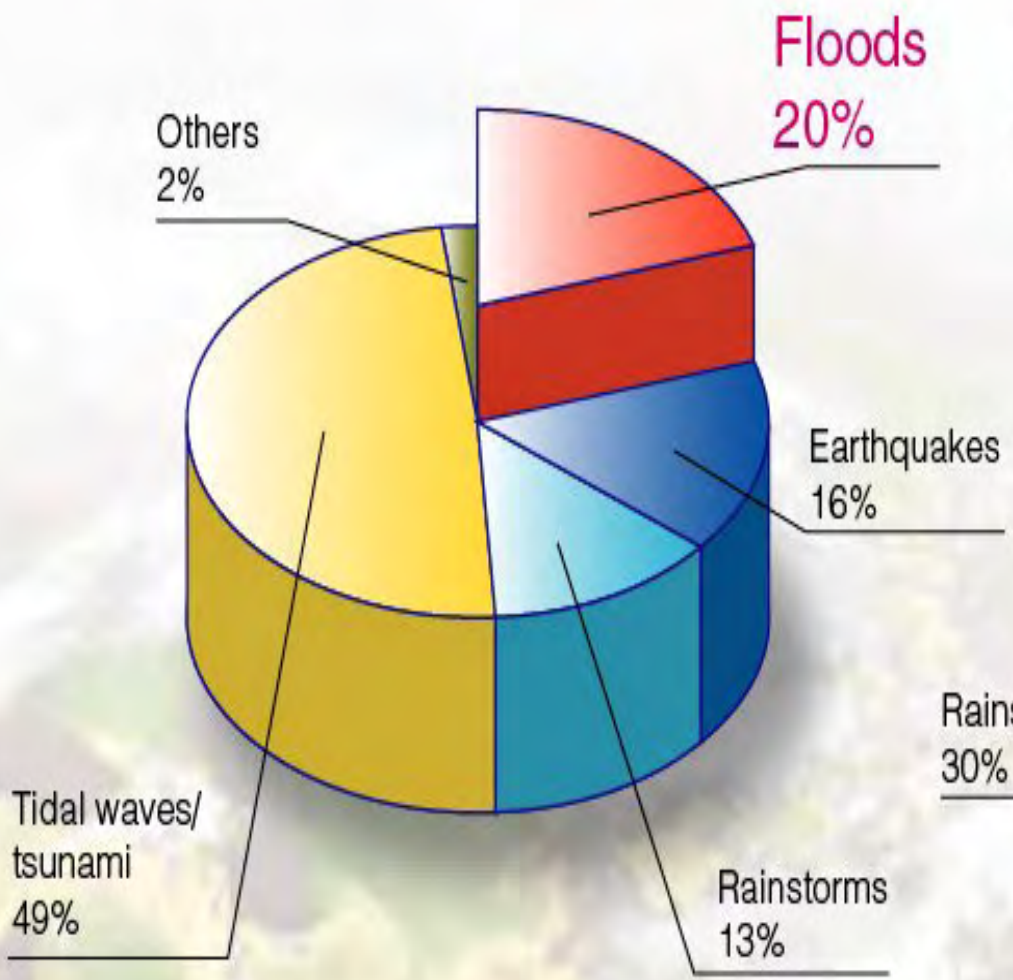
Source : World Disasters Report, International Federation of Red Cross and Red Crescent Societies

World Disasters Report, International Federation of Red Cross and Red Crescent Societies

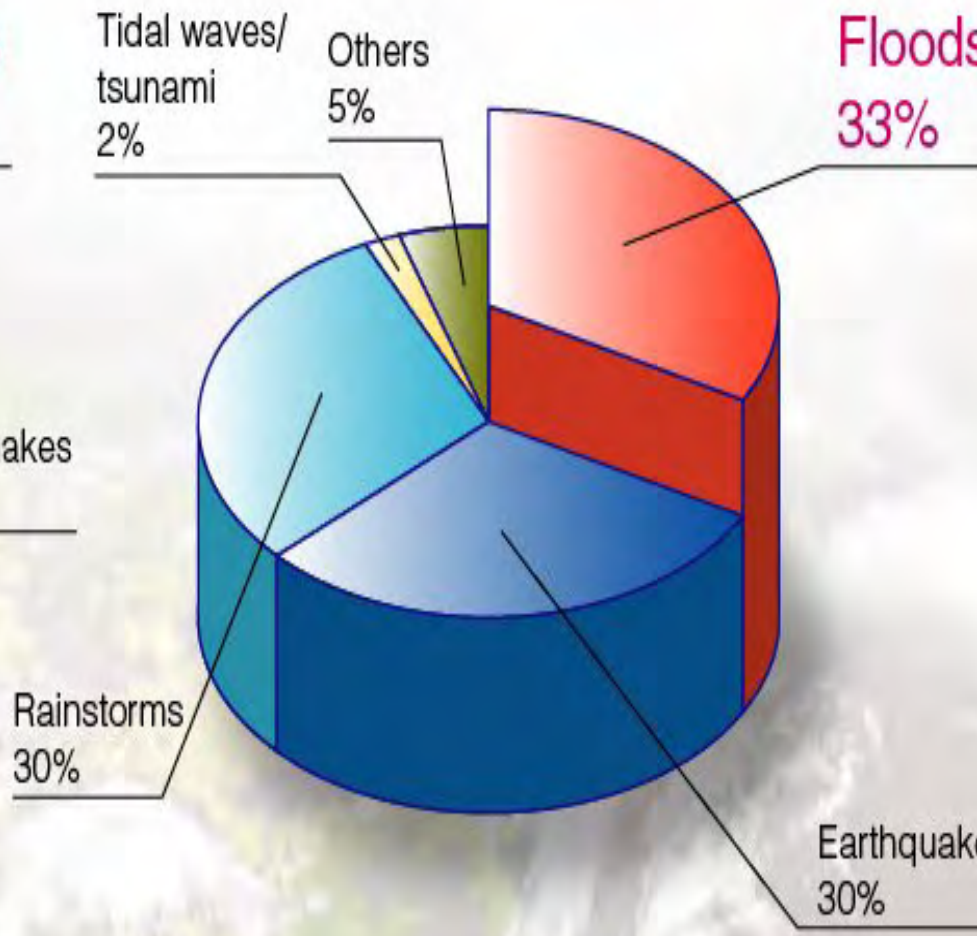
Average Numbers of People Affected by Natural Disasters (1973 – 2002)

World's natural disasters (1995-2004)

Number of deaths : 470,860 people



Economic loss : US$ 49,420,000,000



Source : "EM-DAT" CRED

Flooding

- **Very high vulnerability**
  - **8% of China located in the mid- and down stream parts of the seven major rivers of the country – all subject to floods.**
  - **50% of China's population live in these areas**
  - **665 of total agricultural and industrial product value**
  - **Large floods occur once every two years**
- **Death by drowning**
- **Lack of food/water**
- **Loss of crops/infrastructure**
- **Loss of land/livelihood**
- **Collapse of sanitation, storm-water drainage, and sewage disposal systems**
- **Transmission of waterborne illnesses through unsafe drinking water (i**ncreased exposure to waterborne disease vectors (viruses, bacteria, worms, infectious disease, malaria, etc.)
- **Added pressure on already overstretched public health services**
- **Higher rates of infection/transmission**

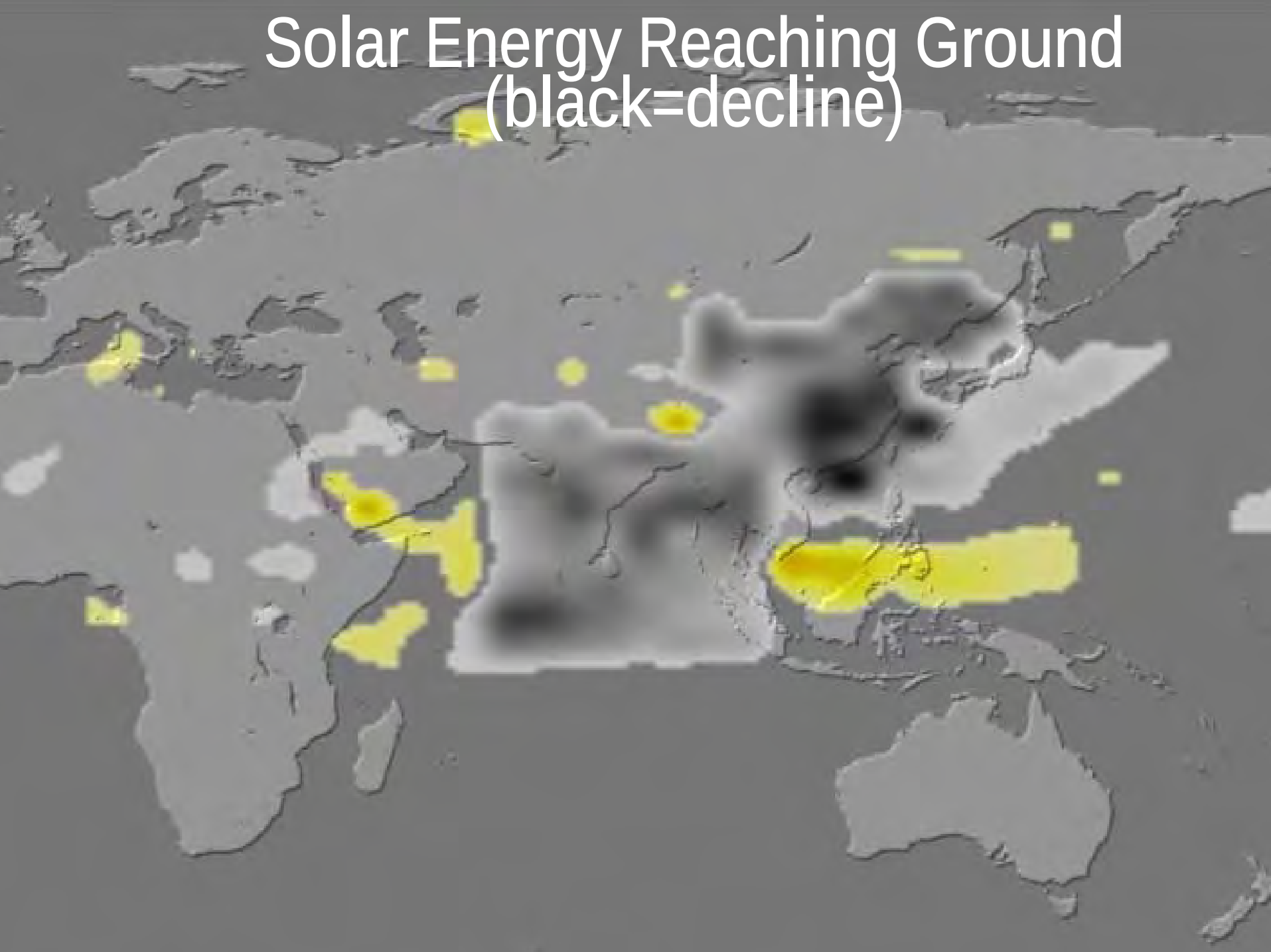
China: Flood Management, Hai-lun, Z. (2005)

Drought

- Northern plains of China
  - 45 percent of China's population (heart of Han Chinese civilization)
  - 58 percent of its cultivated land
  - 19 percent of the nation's fresh water stocks
  - Principal source of water: the Yellow River
  - “Dried up during 21 out of the 27 years between 1972 and 1999.”
- Decreased fresh water supplies
- Less water for irrigation
- Less water for human consumption
- Less productive harvest
- Overuse of secondary habitats, ecosystems
- Forced migration
- Malnutrition/starvation
- Dehydration
- Increased exposure to airborne pollutants
- Increased incidence of respiratory ailments
- Increased exposure to UV radiation
- Skin cancers

“Drought leaves 18 million thirsty in China,” *Xinhua News,* August 20, 2006

Solar Energy Reaching Ground (black=decline)



Direct Human Health

- Climate change is expected to have wide-ranging consequences for human health.
- Heat waves are linked to cardiovascular, respiratory, and other diseases.
- By reducing fresh water supplies, climate changes affect water resources and sanitation.
- Any increase in the frequency or intensity of extreme weather events would pose an immediate threat.
- Food security may be undermined in vulnerable regions.
- Higher temperatures may alter the geographical distribution of species that transmit disease.
- Warmer seas could also influence the spread of disease.
- People will have to adapt or intervene to minimize these enhanced health risks.

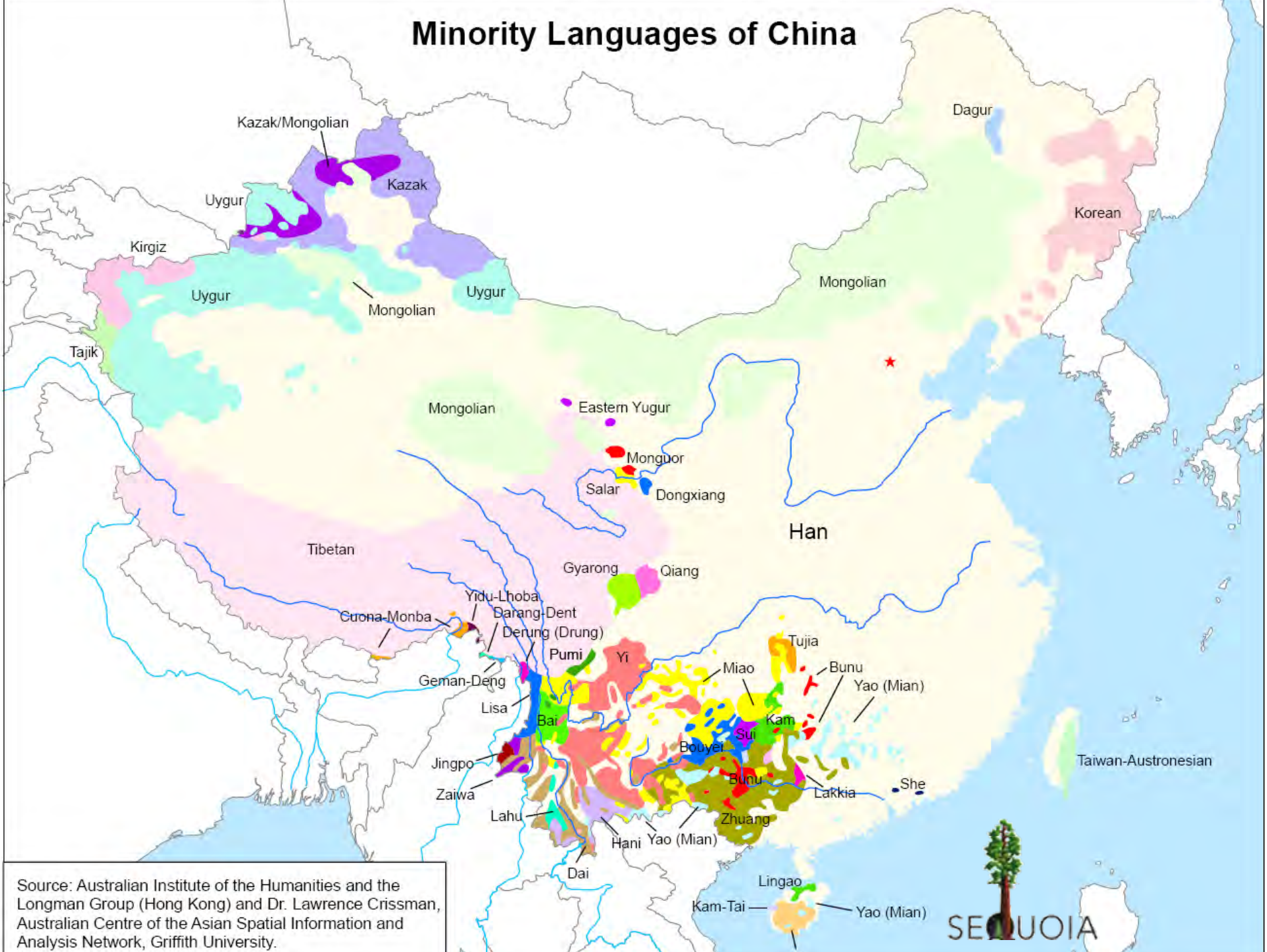
UNEP, UNFCCC, Williams, M. (2002). *Climate Change Information Kit*. Switzerland; 14-14.2.

- Increased exposure to waterborne disease vectors (viruses, bacteria, worms, infectious disease, malaria, etc.)
  - Higher rates of infection/transmission
- Increased exposure to airborne pollutants
  - Increased incidence of respiratory ailments
- Increased exposure to UV radiation
  - Skin cancers
- Immediate effects of typhoons and droughts
  - Flooding
  - Lack of food/water
  - Spread of waterborne diseases
- Decreased fresh water supplies
  - Less water for irrigation
  - Less water for human consumption
  - Less productive harvest

Social/Economic Vulnerabilities

- Lost crops
- Less food for families
- Less money for economy
- Market decline/collapse
- Creation of need to import grain, and the world consequences
- Polarization between people in rural and urban areas
- Forced migration – against social and cultural impediments (linguistic, cultural, social, e.g., Chernobyl)
- Linguistic and other social vulnerabilities
- Disruptions in access to markets
- Mobility, access to emergency and preventative care
- Political responses/miscalculations
- Inability to respond to disasters of proportions previously unseen
- Costs of disaster response/management
- Costs of subsidies and aid to rural families
- Disproportionate impacts to most vulnerable (poor, elderly, children, handicapped)

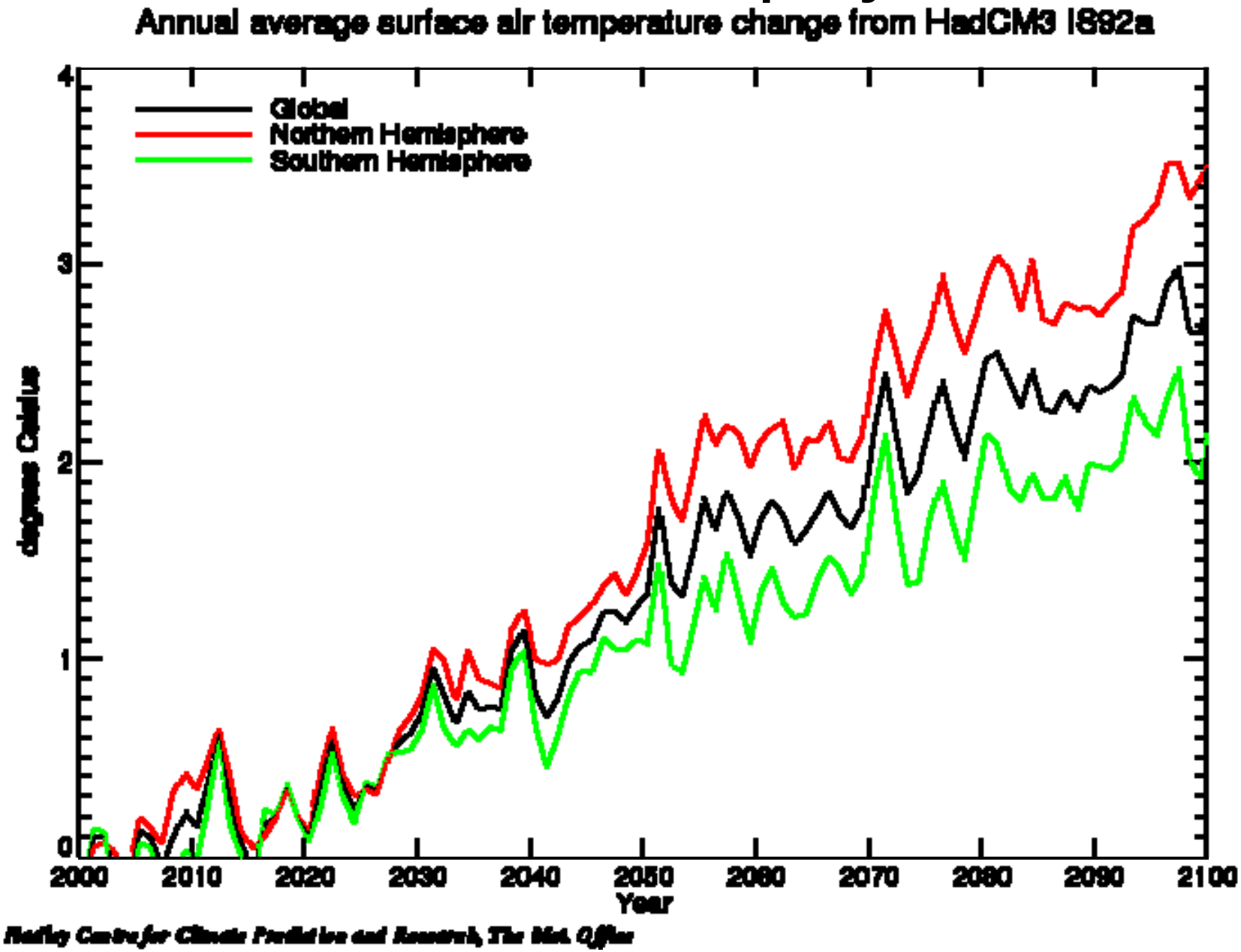
Minority Languages of China



Source: Australian Institute of the Humanities and the Longman Group (Hong Kong) and Dr. Lawrence Crissman, Australian Centre of the Asian Spatial Information and Analysis Network, Griffith University.

SEQUOIA

2000-2100 Climate projection



Conclusions

- **Global climate change (GCC) will dramatically affect planetary and regional weather patterns**
- **Weather affects everything**
- **Effects on distribution, timing, and sequencing of water is of paramount importance**
- **Social *vulnerability* is rapidly increasing and will eventually surpass GCC as principal source of increased morbidity and mortality – the "rich never die"**
- **High-precision, large dataset, analytic use of GIS technology among best tools for understanding distribution of risks**